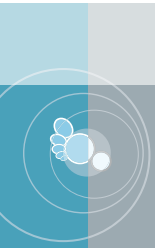
Footwear and Foot Orthoses



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Footwear and Foot Orthoses

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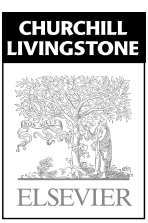

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Foreword

Welcome to '*Footwear and Foot Orthoses*', the 3rd volume in the *Pocket Podiatry* series. This volume is included in recognition of our evolving understanding of the true role of footwear in the maintenance of foot health and the management of foot pathology. Whilst it is tempting to say that Podiatrists have always appreciated the impact of footwear on foot health and disease, the reality is perhaps a little different. A historical emphasis on footwear as a cause of foot pathology may have been derived not from detailed knowledged of its role, but rather due to a limited understanding of other influences – most notably biomechanics. Developing knowledge of biomechanics identified what seemed to be the real cause of foot pathology, which perhaps then had the effect of somewhat marginalising the role of footwear as clinicians focused on orthoses to modify foot and lower limb biomechanics: the 'real' cause of pathology. We are now appreciating the reality that whilst foot and lower limb biomechanics provides us with detailed information on lower limb function, and orthoses provide an important means of addressing biomechanical dysfunction, footwear too is vital and the interaction between these three factors must be appreciated. In this volume Dr. Williams and Professor Nester do an excellent job of reconciling these three elements in a clinically relevant manner, providing insight to our contemporary knowledge and understanding of foot function, footwear, and orthoses. They do so in an objective and informative manner that reflects the experience and knowledge gained from research efforts spanning many years in what is a world-class research facility at the University of Salford.

In common with the preceding two volumes I enjoyed being involved with this project, and draw your attention to two important highlights: firstly, Professor Nester's clinically-oriented synthesis of his wide-ranging research programme that is attempting to uncover the secrets of the multiple functional segments of the foot that have for so long been regarded as of limited importance; secondly, in addition to providing information on the basics of specialist footwear, Dr Williams provides insight to a variety of clinical issues that are vital to successfully utilise this important therapeutic modality. I am grateful to them for undertaking the task of producing this volume and hope that, armed with the information contained within it, you are better prepared than ever to tackle the complex issues surrounding footwear and orthoses that we must deal with on a daily basis.

Ian Mathieson, Cardiff, 2010

Preface

The importance of footwear is inescapable as it features in all aspects of our lives, work, sport and recreation, and social activities. Most of us have many pairs of shoes for different purposes and for different outfits, though maybe not as many as Imelda Marcos, who is reported to have said about her own extravagancy and obsession with footwear:

> *"I did not have three thousand pairs of shoes; I had one thousand and sixty."*

Footwear has an impact on foot health and this impact can be negative, such as incorrect footwear causing skin and structural foot problems, or positive as correct footwear can contribute to good foot health. It is the role of podiatrists and other practitioners who care for the foot, to provide advice on the suitability of footwear for a person presenting with foot problems and with consideration to their personal needs and choices.

As an addition to footwear, foot orthoses (insoles) can improve foot function and foot health and are provided by clinicians for people with a variety of lower limb pathologies. These pathologies may originate from functional problems, such as flat feet, or from systemic problems, such as deformity associated with diabetes or rheumatoid arthritis, and of course there may be a combination of functional and systemic problems. Foot orthoses are worn in footwear, therefore consideration to the footwear suitability is crucial to the success of the orthoses.

As the authors of this Pocket Guide, we aim to provide the practitioner with the knowledge to enable them to maximize the potential for footwear to have a positive impact on foot health, with or without foot orthoses. To achieve this aim, practitioners need to have an understanding of the components of footwear in relation to its fit, suitability and function. As footwear is considered by our patients to be an item of clothing, an understanding of patients' perceptions of footwear in relation to body image is crucial, as is knowledge and skill in supporting behaviour change with footwear choices. The perception of footwear as a vital part of body image is entrenched in its social role throughout history, therefore the development of footwear design and purpose will be explored in this context.

Footwear and foot orthosis design and manufacture is a developing area. With technological advances in manufacture and design, the practitioner is able to guide patients to the footwear that will promote good

foot health. Alongside this is a requirement for the practitioner to have an understanding of footwear issues in relation to the healthy and vulnerable foot, ensuring that evidence is continuously embedded in clinical practice. To this end, the content of this book is based on best available evidence.

With the scale of foot problems in relation to chronic diseases and a growing, aging population, it has never been more essential to maintain and improve foot health. Good foot health is seen as one of the key areas in achieving good mobility and levels of activity and these in turn support the maintenance of a healthy body. Foot orthoses and footwear therefore play a vital role in the achievement of good health.

Dr Anita Williams and Professor Christopher Nester
Salford 2009

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CHAPTER 1

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Principles of foot biomechanics and gait

"A thousand miles starts from beneath one's feet."

Lao Tzu

Introduction

The importance of feet for normal activity and function cannot be overstated and it is often only when feet go wrong that attention is paid to them. We do not pay attention to the ability of the foot to adapt to all the different terrains and activities that we take for granted when everything is going well. We rarely think about the distance that it covers: the average person takes approximately 8000 to 10000 steps per day; and, in a lifetime, walks 115000 miles, which is the equivalent of four times around the world!

The foot is a complex and dynamic mechanism that needs to be understood in its healthy state before we can fully understand the complexity and impact of disease and malfunction on its ability to function normally. Understanding what is considered to be normal function is important in being able to establish the parameters and impact of abnormal function. Further to these factors, knowledge of both normal and abnormal function aids our decision making in respect of the choices in relation to the types of foot orthoses and

footwear available to manage the myriad foot problems that present to clinicians.

The human foot and its precise behaviour during walking and other activities remains one of the last mysteries of the musculoskeletal system. While many texts claim to offer a complete description of foot biomechanics and orthotic or other therapy solutions to foot and lower limb injury, in truth there is much left to discover. With 26 bones, many complex, multi-articular, non-hinge, non-ball and socket joints, over 100 ligaments, and complex layers of interlacing muscles, tendons and ligaments on the plantar surface, it is little wonder it continues to hold its precise biomechanics function a secret. Here, we provide an overview of what is known and can reasonably be extrapolated from the available research and clinical experience.

The foot as a complex structure

One of the most important issues is the fact that while the foot is named as a single anatomical entity, it comprises many individual and variable mechanical parts. These function in an interdependent way because they share many articulations, ligaments and muscles. That is to say that the function of one joint or structure will influence the function of another within the foot. It follows that when we discuss the overall biomechanical function of the 'foot', we must do so in the context that how this overall function is achieved can vary greatly. This is because the constituent parts of the foot are able to behave in different ways under different biomechanical circumstances, and these vary between the feet of different people. It also follows that when we refer to the foot it is intuitive to think that the ankle, as the link between the foot and leg, is the joint where foot biomechanics occurs. In fact, the ankle is simply one joint in a long and complex series of joints connecting the ground to the leg, and we must be mindful not to interpret 'foot' biomechanics as being those of the ankle alone.

Both in the literature and clinical practice, there is emphasis on foot structure and shape, since these are clearly important to foot orthosis and footwear design and effectiveness; however, the foot is a highly dynamic structure whose form or shape under static conditions (i.e., when standing or lying) does not reflect the positions it adopts and the movements it performs during activities such as walking and running. As such, reference to foot shape or posture must reflect the limitations of what shape can tell us about this complex and dynamic part of our musculoskeletal system.

***Key** Concept*

The foot is a highly dynamic structure whose form or shape under static conditions does not reflect the movements it performs during walking and running. Assessment of shape or posture therefore has limitations in respect of what that can tell us about foot function during activity.

Terminology for movement and position of the foot

This may seem a quite obvious and redundant topic but in fact there are great national variations in foot and ankle biomechanics terminology. There is little formally and widely agreed consensus, but there is much copying of good (and bad) practice.

As with all human joint movements and joint positions, those of the foot are described in the sagittal, frontal and transverse planes; however, there is an issue in whether these are defined within the foot, or within the same planes as they are defined for the entire body (Figure 1.1). This causes particular problems for movement descriptions in the sagittal and frontal planes. This is because the feet are abducted in the transverse plane by a variable amount between people. If foot motion is described in the sagittal plane of the body, then the relationship between the foot anatomy and the body planes will vary between people, and this largely defeats the purpose of having standardized planes of motion. The same occurs for frontal plane motion.

As an alternative, sagittal, and frontal, planes can be defined within the foot (Figure 1.2). That is to say, the reference points from which planes are defined are taken from foot anatomy rather than from the whole body anatomy. In this case, the sagittal plane is defined as perpendicular to the supporting surface and aligned anterior/posterior with a line between the centre of the second metatarsal head and the centre of the posterior calcaneus. It follows that the frontal plane is perpendicular to both transverse and sagittal planes, and should therefore lie parallel to the posterior surface of the calcaneus.

Notably, using these definitions allows an important link to be created between experimental biomechanics data on foot motion and clinical terms of reference for foot motion.

- Sagittal plane motion is referred to as dorsiflexion (lifting the distal segment of a joint towards the front of the tibia) and plantar flexion (dropping the distal segment of a joint away from the front of the tibia).

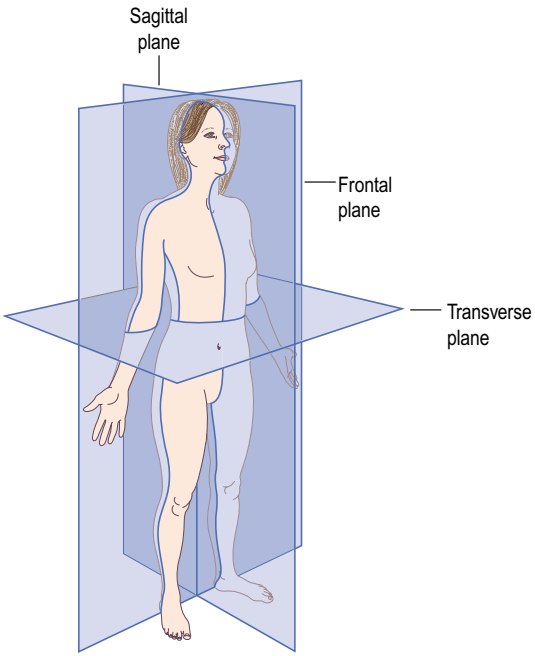

Figure 1.1 Body planes

- Frontal plane motion is referred to as inversion (rotating a joint such that the plantar surface of the foot points towards the other foot) and eversion (rotating a joint such that the plantar surface of the foot points away from the other foot). (These are sometimes incorrectly called varus and valgus movements.)
- Transverse plane motion is adduction (rotating the joint such that the distal segment moves towards the other foot) and abduction (rotating the joint such that the distal segment moves away from the other foot).

Foot pronation and supination are now very common terms, widely referred to by the public, particularly those involved in running. They describe a specific combination of sagittal, frontal and transverse plane motions and are best used to describe the movement of the foot as a whole relative to the floor or leg.

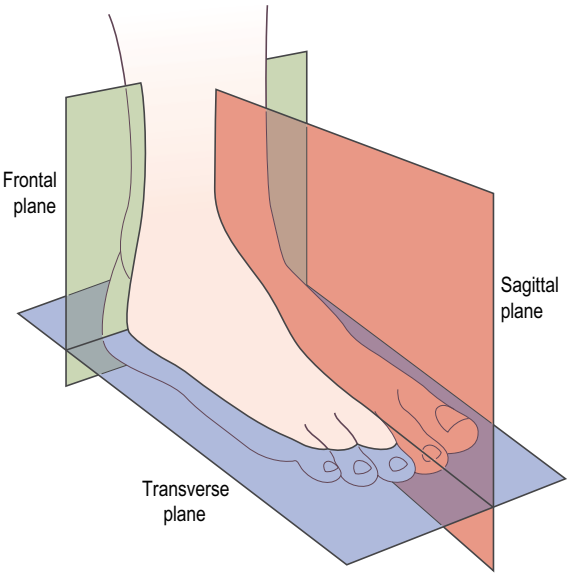

Figure 1.2 Planes of the foot

Key *Concept*

'Varus' and 'valgus' describe position of a joint rather than movement at that joint. A joint in a varus position is inverted and a joint in a valgus position is everted. For example, a varus knee relates to a bowed-leg appearance and valgus knee to a knock-kneed appearance. These terms are sometimes used to describe frontal plane heel position.

Pronation involves lifting the top surface of the foot up towards the front of the tibia (dorsiflexion), while at the same time everting and abducting the foot. In contrast, supination involves plantar flexion of the foot (dropping the foot away from the front of the tibia) while inverting and adducting the foot.

Varus and valgus are terms used to describe foot position in the frontal plane and should not be used to describe foot motion. A varus position suggests that the joint is in a position of inversion, and valgus that it is in a position of eversion; however, to describe the position of any joint, you

must first have a reference position. The foot has a wide range of so-called 'neutral' reference positions. The neutral position is deemed to be the position at which the foot or one of its joints is in its normal alignment, or ideal alignment or parallel to another. There is little consensus as to the value of these neutral positions and much evidence that because they rely heavily on manual palpation, they cannot be identified consistently by different clinicians. It follows that if their identification is not repeatable between clinicians, then the position is not of any real value with regard to diagnosis of foot problems and design of foot orthoses.

The so-called subtalar joint neutral position is rapidly becoming obsolete. A more consistently achievable reference position is foot posture when a person is standing relaxed, and this should be largely repeatable between clinical visits and less susceptible to operator error. Inter-subject comparisons of relaxed standing position are difficult since each person will naturally adopt a different posture for the foot when standing; however, it remains the primary position of reference for assessing foot posture.

Motion at the ankle and subtalar joint

The ankle is formed by the superior aspect of the talus and inferior end of the tibia and fibula; the subtalar joint by the calcaneus and inferior surface of the talus. Since they share the talus, these joints are often described together. Also, what we know of their movements comes from experiments that describe the heel relative to the leg (Leardini et al 2007); this movement comes from the combined motions at these two joints.

Traditionally these joints were described as having quite different functions but contemporary research suggest otherwise (Lundgren et al 2008, Nester et al 2007, Arndt et al 2004). Both are capable of considerable movement in the frontal and transverse planes – in the region of 10–15 degrees in each case, although this appears to vary between people.

The frontal and transverse plane movement between the heel and leg that is described in the literature is a result of frontal and transverse plane motion at both joints, with each often making comparable contributions to the motion in each plane. Traditionally it was considered that frontal and transverse plane motion came from the subtalar alone.

In the sagittal plane, it is clear that the ankle is able to provide far greater movement than the subtalar joint: approximately 40–60 degrees.

Motion at midtarsal and forefoot joints

The most recent research has demonstrated that the joints between the navicular and talus, cuboid and calcaneus, cuneiforms and navicular, and

metatarsals and cuneiforms and cuboid, are capable of considerable movement, far more than previously thought (Lundgren et al 2008, Nester et al 2007). Certainly the range of motion between navicular and talus, and cuneiforms and navicular can be comparable, and there is significantly greater movement of metatarsals 4 and 5 compared with 1, 2 and 3. All of this illustrates the importance of these joints in performing the overall movements of the foot, and it is not the rearfoot which makes the major contribution as is often believed; in fact, all parts of the foot contribute equally to the movements within, and therefore of, the foot.

***Key** Concept*

The midtarsal and forefoot joints are as important as the rearfoot joints in producing foot motion.

Medial arch of the foot

The medial longitudinal arch of the foot has attracted considerable attention because it provides a very visible indicator of the pronated or supinated position of the foot and because it is often associated with foot problems and injury. The higher the arch of the foot, the more supinated the position of the foot and vice versa.

The medial arch is formed by the calcaneus, talus, navicular, medial cuneiform and first metatarsal, and so the position and movement of all these bones can affect the medial arch height. In addition, the surface of the arch is formed by the muscles and soft tissues on the plantar surface of the foot, and their size and condition can also influence the visual appearance of arch height (Figure 1.3). The forces generated by these muscles and the plantar fascia will produce plantarflexion moments at all the joints of the medial arch and are therefore able to directly influence the pronated (Figure 1.4) or supinated positions of the foot.

The foot and lower limb in gait

Gait is the primary physical activity we all undertake and it remains the focus when investigating possible aetiologies of foot and lower limb problems, and when designing foot orthoses and footwear.

In the simplest terms, there are three parts to the gait cycle. In phase 1, the body accepts weight as the foot hits the ground. In phase 2, body weight is moved from behind the foot to in front of it. In phase 3, the foot prepares to leave the ground and propels the body forwards into the step of the adjacent foot.

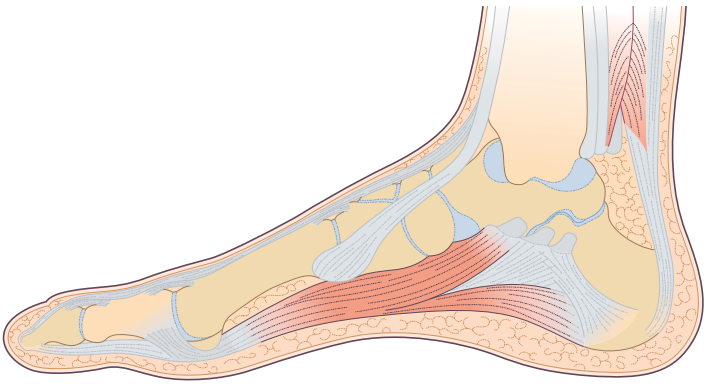

Figure 1.3 Medial arch of a normal foot

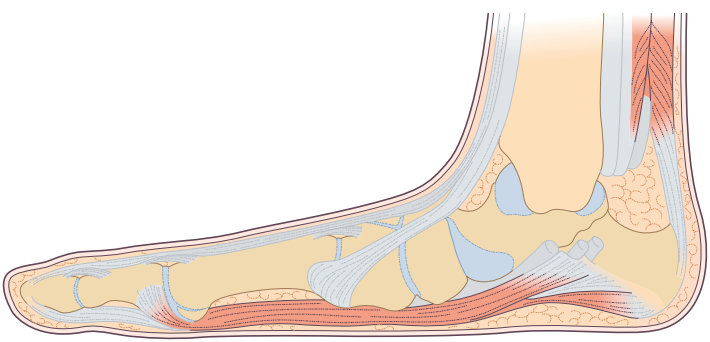

Figure 1.4 Medial arch of a pronated foot

For the majority of gait, two feet are on the ground: when one foot is in phase 1 (just contacting the ground), the other is in phase 3 (preparing to leave the ground); when one foot is in phase 2, the other foot is off the ground.

The behaviour of the joints and structures of the foot in these three phases can be complex and is highly variable between people. The foot performs an overall function in gait, but how its various structures behave to achieve the overall function is not always consistent between people. There are many trends with regard to foot biomechanics during gait, but also much evidence that not everyone demonstrates the same movement

or loading patterns. Thus, every patient is individual in how their foot performs.

Phase 1 of gait

The foot normally contacts the ground via the posterior/lateral part of the plantar surface of the heel. The heel is typically inverted relative to the ground and to the leg, and the plantar surface of the foot angled 90 degrees or more relative to the leg (Figure 1.5).

Ankle plantarflexion brings the rest of the heel and then midfoot into ground contact. The heel everts relative to the leg and ground and abducts relative to the leg.

The force applied to the body by the ground rises rapidly in this period, reaching a peak of typically 1.2 times body weight. Some people exhibit a very high loading rate in the first few milliseconds of gait when walking barefoot, a so-called heel strike transient, but this disappears with most footwear as the shoes help attenuate the rate at which load is applied to the plantar surface of the foot.

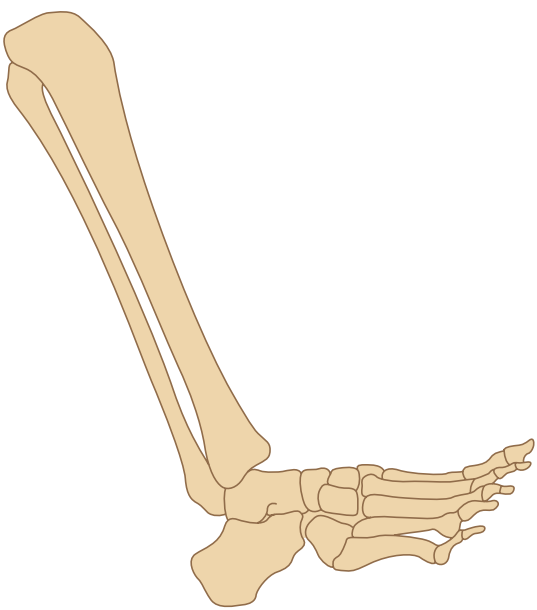

Figure 1.5 Phase 1 heel strike

Foot pressure starts at the proximal and lateral aspect of the heel, with the contact area quickly increasing as load is accepted under the foot and as the heel plantarflexes.

The position of ground contact is important because it determines how the forces from the ground act around the ankle and subtalar joints. If initial contact is made with the ground by the distal part of the heel or even the midfoot, then the ankle will tend to dorsiflex, not plantarflex. If the initial contact is on the medial side of the heel, the heel will tend to invert after heel contact, not evert as is normally the case.

Many describe the foot as behaving as a 'mobile' adaptor in this phase of gait, because it moves to adapt to the walking surface. In fact, it is no more mobile in this phase than any other, but it is true that the foot moves in response to the forces it experiences from the ground and these are dependent upon the terrain.

Phase 2 of gait

From being only under the heel in phase 1, the load under the foot spreads to the lateral aspects of the midfoot area and gradually to the forefoot, too (Figure 1.6). Eventually the heel, mid-, forefoot and toes are loaded. Thereafter, the upper body is moved from behind to in front of the foot, and load is progressively reduced under the heel and increased under the mid- and forefoot. Eventually the heel leaves the ground.

During this period the tibia has begun to move around the foot and thus the ankle and entire foot dorsiflexes relative to the leg. Within the foot, as the mid- and forefoot are progressively loaded, the joints experience an increased tendency to dorsiflex. These forces are resisted by the muscles and ligaments on the plantar surface of the foot, including tibialis posterior and the long flexor muscles. These muscles also assist the soleus and gastrocnemius muscles in resisting excessive forward motion of the tibia as the ankle dorsiflexes.

Proximal to the ankle and as the upper body is moved forward of the foot, the femur and tibia begin to rotate externally. As a result of the mechanical coupling of the tibia, talus, calcaneus and midtarsal joint, this external tibial rotation supports supination of the foot, which typically occurs once the tibia is forward of the ankle. The precise pattern of supination can vary greatly between people, with some feet supinating from soon after forefoot loading, and others not supinating until well into the propulsive phase of gait (phase 3). Supination is further aided by the action of the posterior leg and plantar foot muscles as they resist dorsiflexion within the foot.

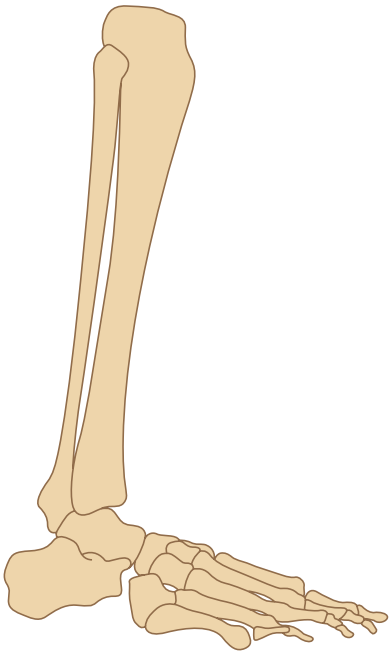

Figure 1.6 Phase 2 mid stance

The force applied to the body by the ground reduces during this phase because the body mass is moving upwards away from the ground. Loading falls to a minimum of about 0.8 times body weight at around the time when the hip is above the ankle.

Phase 3 of gait

The site of load under the mid- and forefoot continues to move distally as the heel, then midfoot, and eventually the forefoot become unloaded. Load moves from the lateral midfoot and forefoot towards the first metatarsal head and first toe (Figure 1.7). This occurs not because of foot pronation, but because the upper body moves from above the weight-bearing foot towards the other foot, which has just entered phase 1 of gait.

During this period the ankle, midtarsal and other midfoot joints all plantarflex to assist in moving the body forwards into the next step. The

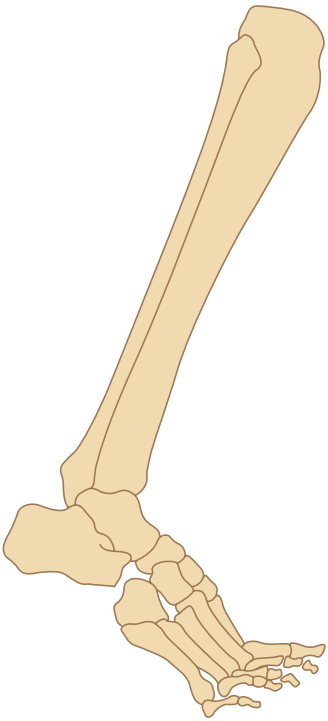

Figure 1.7 Phase 3 heel lift

plantar foot and posterior leg muscles are active in this period and support this plantarflexion movement. Overall, the foot may plantarflex 15–25 degrees relative to the leg, with the different rear-, mid- and forefoot joints making variable contributions. As these joints plantarflex, the first toe continues to dorsiflex, peaking at 40–50 degrees just prior to the first toe leaving the ground.

Throughout phase 3, the first toe remains relatively fixed on the ground and thus it becomes the single point around which the foot and entire body rotate. There are a number of popular ideas regarding the causes and consequences of reduction in first toe dorsiflexion during stage 3 of gait. Certainly, pronating a weight-bearing foot will tend to reduce the

available range of hallux dorsiflexion, and supinating the foot will increase the range. It does not follow, however, that a foot that is in a pronated position has too little dorsiflexion available, nor that the foot should be made to supinate in order to increase the range of hallux dorsiflexion. The relationship between increased pronation of the foot and reduced hallux dorsiflexion may be due to dorsiflexion of the first metatarsal during foot pronation and the subsequent change in the relationship between the articular surfaces of the hallux and the first metatarsal head.

From the end of phase 2 and throughout phase 3 the tibia externally rotates. This supports the continued supination of the foot. Many people refer to the foot as 'becoming' a rigid lever in this phase of gait. In fact since the joints of the foot all move throughout this phase, it is not rigid at all and no more rigid than in any other phase of gait; however, it is true that for efficient propulsion it is ideal for the foot to be able to resist the strong dorsiflexion moments created by the ground reaction force, else the foot would simply collapse. A stiff structure would indeed be better than a flexible structure to resist these forces; however, the foot moves while at the same time resisting these forces owing to the action of the posterior leg and intrinsic foot muscles, supported by the plantar fascia and movement of the leg, thigh and upper body. This provides resistance to the dorsiflexion moment caused by the ground reaction force and provides a suitably stable structure against which the body can push against the ground and move forwards.

The force applied to the body by the ground rises during this phase because the body mass is moving down towards the ground and the foot pushes against the floor as the foot plantarflexes. Loading peaks at around 1.2 times body weight. Loss of this second peak in the ground reaction force indicates a loss of efficient propulsion and lack of plantarflexion as the foot pushes down and backwards against the ground.

Summary

This chapter has described the foot as a complex and dynamic mechanism, and has provided an understanding of the basics of normal foot function. This complexity increases when the foot is affected by disease, injury or other malfunction. The next chapter will explore the impact of aging and systemic disease on the foot in order that an understanding of the specific requirements in the management of these problems has a clear rationale.

Review questions

Reflection

1. Can I describe the three phases of gait?
2. Do I understand the role of rearfoot and forefoot joints in the motion of the foot?

Self-assessed questions

1. What are the three planes of the foot that describe joint movement and position?
2. Describe the movements that occur in the three planes of the foot.
3. Name the two terms used to describe movement of the foot as a whole relative to the floor.
4. How much motion (in degrees) is normally available at the subtalar joint?
5. Which bones form the medial arch of the foot?
6. Identify the key components of the three phases of gait.

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CHAPTER 2

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The impact of aging and systemic diseases on foot and lower limb mechanics

"I don't like my feet much…they are the thing that stop me walking normally…I have learned to fight the pain to try and walk better…then that shows in your face…"

Rose

Introduction

The impact of systemic diseases on feet cannot be underestimated in respect of pain, limitation of activities and body image. There are many factors that affect normal foot structure and gait, ranging from genetic tendencies for specific foot types to systemic diseases. Additionally, the normal aging process contributes to alteration in normal foot structure and gait. Some individuals experience the impact of a combination of factors, for example an older person with diabetes and abnormal foot function associated with a familial tendency for the foot type that develops hallux rigidus. In cases such as this, orthoses are a particularly important aspect of management in the prevention of pressure-induced problems such as foot ulceration. Although this chapter is divided into

sections relating to aging, diabetes and rheumatoid arthritis, practitioners should not forget that many patients do in fact present with problems associated with a combination of some or all of these. Nevertheless, foot orthoses (and indeed appropriate footwear, covered in Chapter 7) are an important consideration in relieving symptoms, improving mobility and preventing limb-threatening lesions. The purpose of this chapter is to give the reader some indication of the importance of assessing patients with these conditions for foot orthoses and footwear. In order to do that, some of the underlying problems associated with these conditions are detailed as they influence decision making in relation to the design and function of the various interventions.

It is not intended that this chapter be a definitive guide to these conditions and so the reader is provided with several references and suggestions for further reading.

The aging foot – structure and mobility

Foot problems lead to some of the most distressing and disabling symptoms and conditions affecting older people. The ability to remain pain free and ambulatory is a key element in successful aging. Foot and related problems and their impact may be local, or they may be associated with systemic conditions caused by disease. The medical conditions that place older patients most at risk for serious foot problems are vascular, neurological and endocrine diseases, as well as arthritis.

Feet are put under pressure during static and dynamic loading, with this pressure being compounded by the hard surfaces on which we walk. This potentially creates repetitive micro- and macro trauma, and any inability of the foot to adapt to stress produces inflammatory changes in bone and soft tissue. These problems may manifest in symptoms of pain, discomfort and loss of function associated with the structure of the foot, involving joints, tendons and ligaments. Specifically, foot problems such as plantar fasciitis, metatarsalgia, the development of lesser toe deformity, and deformity of the hallux are common problems in the aging foot (Helfand and Jessett 1998). Because of limited joint mobility and associated symptoms, older people may lose the normal heel-to-toe motion in the feet when walking, and many adopt a shuffling gait.

***Author** Note*

Minor trauma in the aging foot can lead to fracture, therefore a stress fracture should be suspected when foot pain is severe and prolonged.

There may be progressive loss of muscle mass and atrophy of tissue as a consequence of disease, decreased function or lack of activity, all of which increase the risk of osteopenia in older adults. Because even minor trauma can result in a fracture, a stress fracture should be suspected when foot pain is severe, prolonged and not otherwise explained.

Foot problems, associated foot pain and inappropriate footwear can contribute to trips and falls in the elderly. Owing to osteopenia, bones are more vulnerable to fracture, and the most common sites of fracture injuries include the neck of femur and the wrist. Any elderly person presenting in clinic should be questioned about falls and near misses. If there is a history of falling or tripping, they should be referred to a 'falls team' for more detailed assessment. Certainly their footwear-wearing habits and footwear suitability should be addressed, and the need for accommodating foot orthoses to relieve painful symptoms and improve stability must be recognized.

***Key** Concept*

Older people should be questioned about falls and near misses. Footwear suitability and the need for accommodative foot orthoses should be assessed and if there is a history of falls, refer to a specialist 'falls team'.

In summary, degenerative diseases commonly impact the elderly person's foot as a consequence of severe or repetitive trauma, inflammation, metabolic change, repeated and chronic micro-trauma, strain, obesity and osteoporosis. These conditions can increase pain, limit mobility and threaten the older person's ambulatory status.

Impact of diabetes on foot structure, foot pressure and gait

Peripheral neuropathy is a common problem for many people living with diabetes, with up to 50 per cent presenting at diabetic foot clinics diagnosed with the condition (Edmonds and Foster 1999).

Peripheral neuropathy can affect many of the body's nerve pathways, including the sensory, autonomic and motor nerves. Loss of sensation, known as sensory neuropathy, is commonly observed in the diabetic foot because raised levels of circulating glucose in the bloodstream can over time permanently interfere with normal nerve function. The typical clinical features include a loss of sensitivity to touch, pain, temperature and vibration. It can affect the motor pathways that innervate skeletal muscle, and autonomic pathways that innervate smooth muscle in the blood vessels,

Figure 2.1 Structural changes in the neuropathic foot

and is often referred to as a polyneuropathy. Motor neuropathy can cause wasting of the small muscles of the foot. This can lead to characteristic structural changes, including claw toes and prominent metatarsal heads (van Schie et al 2004) (Figure 2.1).

When this is coupled with sensory loss, these areas are particularly vulnerable to increased repetitive pressures and altered time loading, resulting in callus formation, which is known to be the precursor to foot ulceration (Young 1992) (Figure 2.2).

Foot pressure systems (Figure 2.3) can be useful in clinical practice as well as in research in order to evaluate the impact of increased foot pressure and time loading and the effect of orthoses in dealing with these problems. It is also useful to evaluate if by offloading one area of the foot, another vulnerable area is created.

Many of the gait abnormalities recognised in patients with diabetes are a direct consequence of motor neuropathy which leads to muscle wasting. Atrophy of the muscles in the foot can result in an altered arch profile, typically presenting in the diabetic patient as a high-arched foot. The increase in arch height reduces the area of the foot that makes contact with the ground, resulting in a further increase in pressure under the contact areas. The site that is known to be subject to increased pressure is under the first metatarso-phalangeal joint and together with sensory neuropathy it becomes an area of potentially increased time loading.

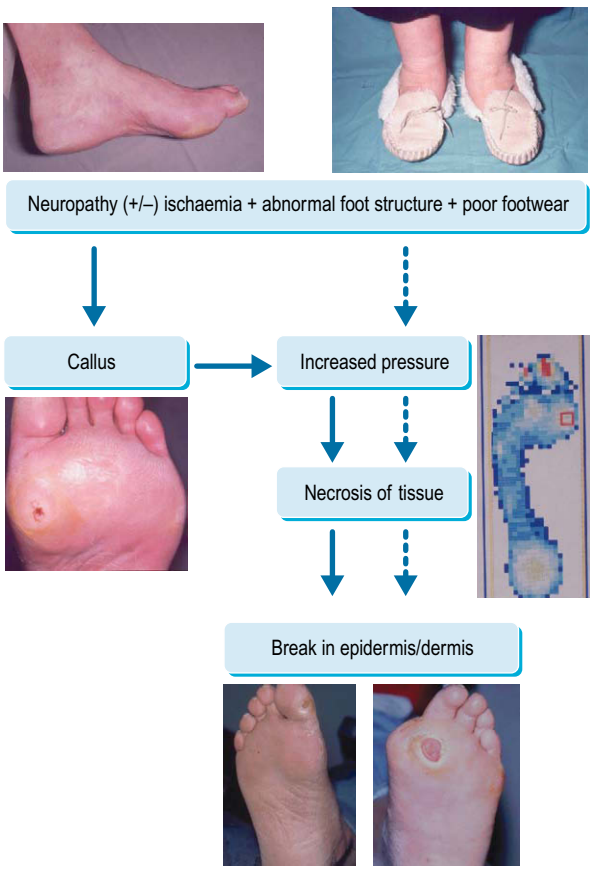

Figure 2.2 Pathway to foot ulceration in the diabetic foot

***Author** Note*

Foot deformity plus neuropathy lead to increased repetitive pressure and altered time loading over vulnerable areas of the foot which in turn cause callus and ulceration. The commonest site for ulceration in the neuropathic foot is under the first metatarso-phalangeal joint.

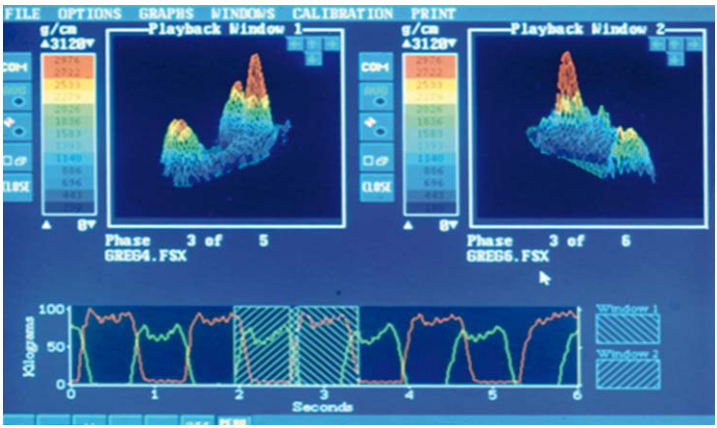

Figure 2.3 Foot pressure measurement

Motor neuropathy and muscle wastage combined have a detrimental effect on gait. Sensory neuropathy alters the patient's perception of their body positioning, which can also have a detrimental effect on gait. Patients with impaired proprioception may present with an ataxic (uncoordinated) gait, postural instability, balance deficits and an increased risk of fall-related injury (Van Deursen and Simoneau 1999). If the tibialis anterior muscle is affected by motor neuropathy, the patient will walk with rapid, uncontrolled foot drop during the initial contact phase of gait. The clinician can hear this as a foot slap as the muscle fails to control dorsiflexion. This problem reduces the capacity of the foot to absorb shock.

In summary, the diabetic neuropathic foot may demonstrate increased foot pressures and time loading, and contribute to instability and alterations in gait. These problems can be helped with foot orthoses. As well as examining the foot for structural problems, a neurological assessment is imperative in these patients as this will impact on the clinical decision making in relation to foot orthoses design, footwear and the advice that is given with these interventions.

Impact of rheumatoid arthritis on foot structure, foot pressure and gait

Symmetrical small joint polyarthritis is the classic early manifestation affecting the metatarso-phalangeal and proximal interphalangeal joints in

the foot. Foot pain is a major problem in patients with rheumatoid arthritis (RA). About 90 per cent of people with RA complain of painful feet during the course of their disease, with most patients suffering from the onset (Michelson et al 1994, Vainio 1956). This can lead to joint instability, difficulties in walking and limitation in functional ability that restrict activities of daily living. It is now known that deformities in the feet of people with RA result from a combination of synovitis and mechanical stresses. Recent work has provided some insight to some of the mechanisms leading to these changes (Turner et al 2006) and this means potentially that orthotic intervention can be targeted in order to arrest or slow the rate of change.

***Key** Concept*

As we know that deformity in the RA foot is caused by a combination of inflammation and abnormal mechanics, it is potentially preventable if the mechanics of the foot are managed appropriately.

Chronic synovial inflammation and progressive erosion of cartilage and bone have been described for the tibiotalar, subtalar and midtarsal joints in RA. The resultant foot deformity is classically described as pes planovalgus with retraction or clawing of the lesser toes and hallux abductovalgus (Figure 2.4).

The subtalar joint also contains important ligaments that contribute to the stability of the ankle joint complex (AJC), namely the talo-calcaneal and cervical ligaments, which are particularly vulnerable to pannus

Figure 2.4 RA foot – advanced deformity

formation in advancing disease. The subtalar joint is more vulnerable because of its complexity, vulnerable supporting structures, and its pivotal role in walking. Structurally, the clinical manifestations are valgus deformation of the rearfoot, usually accompanied by medial longitudinal arch collapse, and this is estimated to occur in 67 per cent of patients with RA.

Dysfunction of the tibialis posterior tendon has been associated with severe pes planovalgus deformity (Figure 2.5) in relation to the presence of tenosynovitis, longitudinal tears and rupture.

Progressive deformity is associated with increased disease duration, and pathology in the ankle and tarsus, with synovitis, tenderness and pain.

Platto et al (1991) demonstrated significant gait impairment in RA patients with rearfoot pain and valgus deformity. The appearance of valgus heel deformity, medial longitudinal arch depression and bulging of the talonavicular complex are often sufficient to clinically diagnose a hyperpronated foot. The talonavicular joint inflammation and deformity have an important and potentially contributory role to play in the development of foot deformity (Woodburn et al 2002).

In addition to synovitis in the subtalar and talonavicular joints, the forefoot joints are often affected. Daylight sign is the classic picture of

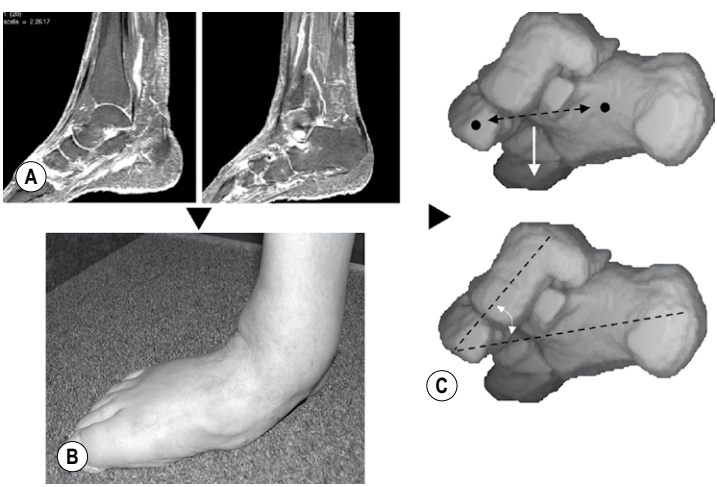

Figure 2.5 Severe pes planovalgus deformity associated with RA. A – Two sagittal slices of a post- gadolinium MR sequence showing disease activity in the tarsal joint region
B – the clinical picture of severe pes plano valgus deformity
C – 3D rendition of the calcaneus, cuboid, talus and navicular

widening of the space between adjacent toes. Patients often report that they can no longer fit into their existing footwear. Further to this, they may complain of pain in the forefoot, often described as Morton's neuroma; but in this case, rather than swelling of the interdigital nerve itself, it is more likely that the swelling is causing compression on the nerve. The presentation is the same, however, with sharp radiating pain which is worse on weight bearing and is reproduced by pressure across the metatarso-phalangeal joints. Additional problems in the foot may be Achilles bursitis, calcaneal spurs and rheumatoid nodules both in the heel pad and other areas of pressure.

When walking, people with RA may present with altered gait. Stride length can be shortened, particularly in patients with forefoot pain, and as we know that stride length is an indicator of joint loading, this strategy may be protective for symptoms and loading as a component of developing deformity. In addition to shortening stride length, people with painful RA foot problems can be observed reducing speed and increasing 'double limb' support time, that is, increasing the time spent on two feet rather than in the normal gait cycle, and ultimately developing a shuffling gait once rigidity of the foot joints compounds this adaptation in gait. There is some indication from early work by Rome et al (2009) that patients with RA also have problems with postural stability. Patients in this exploratory study displayed a significantly larger centre of pressure excursion in the anterior–posterior direction during quiet standing when compared with a non-rheumatoid arthritis control group, suggesting that postural control mechanisms such as ankle strategies are impeded by the disease process of RA.

Gait studies of AJC function in RA patients with long-standing disease have shown kinematic dysfunction characterized by increased eversion from heel strike through midstance, both in terms of magnitude and duration, and decreased inversion motion during the propulsive stage of stance. This is associated with moderate to high levels of foot impairment and associated disability. Furthermore, gait analysis detected subtle but functionally important changes to the biomechanical function of the foot. Assessment using 3D kinematics (reflective markers placed over landmarks of the foot, tracked by cameras as the patient walks) of the AJC aids evaluation of rearfoot function and could be used to identify those individuals who would benefit from foot orthoses before irreversible joint changes occur. It is difficult to measure simultaneously all the small joints of the foot using 3D kinematics and they have to be grouped together into functional units. As it is difficult to locate the markers because of soft-tissue problems and the complex anatomy of the foot, it is essentially reserved for use in research.

Plantar pressure distribution under the foot can be measured using platform or in-shoe pressure measurement systems. Peak pressure and the pressure time integral are frequently higher than normal in the forefoot, and associated with pain, stiffness and deformity. In pes planovalgus, the collapse of the medial longitudinal arch is associated with increased contact and force in the midfoot. Plantar pressure measurement can be used to evaluate the effectiveness of foot interventions such as foot orthoses and footwear, particularly using in-shoe systems. This is useful for both research and clinical purposes in evaluating the impact of foot orthoses and also identifying vulnerable areas that may ulcerate. Vasculitis (inflammation and necrosis of blood vessels) and neuropathy are also considered as potential factors in the development of foot ulceration (Figure 2.6).

Abnormal foot and limb structure + poor footwear
Callus?
Increased pressure (+ vasculitis and/or neuropathy)
Necrosis of tissue
Break in epidermis/dermis

Figure 2.6 Pathway to ulceration in the RA foot

Author Note

Patients with RA presenting with deformity, vasculitis, neuropathy and inappropriate footwear are at high risk of ulceration. Accommodative foot orthoses should be considered in addition to protective footwear.

In contrast to the evidence supporting reduction of callus as an effective way of reducing damaging foot pressure in the diabetic foot (Young et al 1992), there is evidence (Davys et al 2005) that the pain associated with callus in the RA foot is more likely to be caused by inflammation of the plantar bursae and/or boney erosions occurring around the metatarsal heads and proximal phalanges'. This study found that the metatarso-phalangeal joints with overlying callus were more eroded than those without, suggesting a relationship between local stresses, joint damage, callus formation and painful symptoms. The authors of the study indicate that callus debridement should continue as there is no clear evidence over a longer time period that leaving the callus may not result in increased symptoms and the risk of ulceration. They strongly recommend provision of other modalities of treatment. This would include foot orthoses and footwear therapy as well as considering referral for forefoot surgery.

Author Note

Callus reduction should be carried out with caution and foot orthoses should always be supplied to manage the excessive foot pressures leading to the callus formation.

Summary

Alterations in foot structure and gait have significant and often devastating consequences for people with diabetes and rheumatoid arthritis and these problems are compounded with increasing age. An understanding of these foot problems is necessary in order to be able to provide the correct orthoses and footwear. These interventions are covered in the following chapters.

Review questions

Reflection

1. Can I identify the structural changes that occur in feet affected by:
   - the complications of diabetes?
   - rheumatoid arthritis?

2. Can I list the factors that lead to foot ulceration in:
   - the diabetic foot?
   - the rheumatoid foot?

Self-assessed questions

1. What should be suspected if an older person presents with persistent and severe pain in the foot?
2. What are the two components of pressure that have the potential to cause callus formation in the diabetic foot?
3. How does diabetic motor neuropathy affect a person's gait?
4. What are the main presenting symptoms in the foot affected by RA early in the disease process?
5. What are the two factors that may lead to deformity in the RA foot?
6. How do established RA foot deformity and the symptoms associated with it affect gait?

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CHAPTER 3

Foot orthoses

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Introduction

With the plethora of foot orthoses available for the clinician to choose from, it is often a difficult task to match the correct design to the presenting foot problems. Without an understanding of the relative advantages of the different types of orthoses available, it is impossible to make an informed selection for each patient. In attempting to derive some understanding of the effectiveness and mechanisms of action of foot orthoses to inform orthotic selection, a key difficulty lies in understanding exactly what is meant by the term 'foot orthoses'.

Terminology to describe foot orthoses

Any material placed between the sole of the foot and the inside of the shoe could be considered a foot orthosis since it will influence the forces acting on the foot; however, a great deal of time has been dedicated to classification and comparison of different types of foot orthosis. They are commonly classified according to the method of manufacture, being made either bespoke to the patient's foot via a cast of the foot (often termed 'casted' or 'bespoke' orthoses) or 'off-the-shelf' orthoses, that are standardized in their shape as determined by the manufacturer (often termed 'prefabricated' or 'preformed' orthoses). Orthoses may also be classified by intended function, so an orthosis with an arch support and made of rigid

materials will be expected to reduce foot pronation (a functional foot orthosis), whereas a flat insole made from layers of cushioning material is intended to reduce forefoot pressures (an accommodative orthosis). As a further complication, all of these may or may not have additional wedges or raises under the heel and forefoot to influence foot motion and load distribution, and the features of a functional foot orthosis and an accommodative foot orthosis are commonly combined.

Design of foot orthoses

A great deal of attention is paid to the shape of the upper surface of the orthosis, especially the arch and heel areas; however, the *effective* surface of the orthosis, that is the shape the orthosis adopts under loading, is perhaps the most important shape to consider. This depends upon the original shape of the orthosis, the material properties of the orthosis and the load applied to it. Two orthoses of the same shape will function very differently if they are made from different materials, and they will adopt very different effective shapes.

A primary choice in the provision of orthoses is whether to use 'off the shelf' orthoses that have a preformed shape, or whether to cast the foot and manufacture a bespoke orthosis. Practice has changed considerably since the 1980s, so now there is far greater use of prefabricated orthoses than casted orthoses, with no appreciable change in clinical outcomes being reported.

The routine use of casted orthoses is questionable. Advocates of casted orthoses make much of the need for intimate contact between the surface of the orthosis and the foot in order that pronation of the foot can be best controlled. While it seems obvious that making an orthosis to the shape of a specific patient's foot will create an improved fit between the foot and the orthosis, there is no evidence that this is the case, nor that clinical outcomes are better from casted orthoses. It should be remembered that the cast of a foot is taken with the foot in a static position, whereas we know that the foot moves a great deal during gait. Also, many manufacturers who construct the casted orthosis for the clinician modify each cast to smooth any areas resulting from the casting process, or to compensate for poor casting technique. This is also done to reduce the likelihood of poor fitting (which may necessitate modifications to the orthosis by the manufacturer). As a result, the precise contour that was captured in the cast will be lost. There is good evidence that the precise shape of the cast is highly dependent upon the clinician taking the mould, so two casts of the same foot will never look the same and will often look radically different.

Prefabricated foot orthoses

Given the wide range of prefabricated orthoses available on the market, and the range of materials and shape they offer, it is likely that for the vast majority of patients (> 80 per cent) a functionally valid and clinically effective insole can be found without the need to cast the foot (see Figures 3.1 and 3.2).

This offers several important advantages. First, the cost of off-the-shelf orthoses is much less than a casted hand- or CADCAM-manufactured orthosis. Second, most health services carry stocks of orthoses and so the patient can receive them immediately, removing the need for a fitting appointment, and delivering the clinical benefit to the patient without delay. Third, if the orthosis proves effective, more of exactly the same orthosis can be easily ordered, whereas for a repeated prescription of a

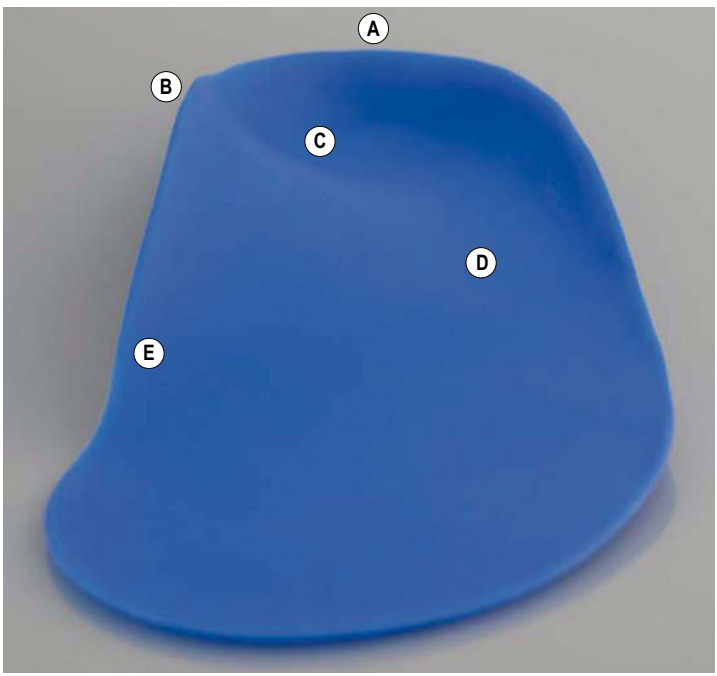

Figure 3.1 Prefabricated foot orthosis – anterior view. Key: **A** = deep heel cup, **B** = top of arch, **C** = start of arch, **D** = medial/lateral arch, **E** = end of arch Salford insole HYPERLINK "http://www.salfordinsole.co.uk/"

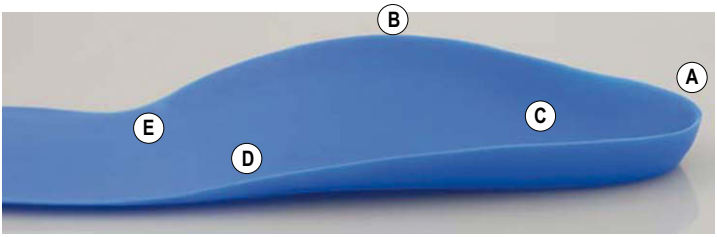

Figure 3.2 Prefabricated foot orthosis – lateral view. Key: **A** = deep heel cup, **B** = top of arch, **C** = start of arch, **D** = medial/lateral arch, **E** = end of arch. Salford insole HYPERLINK "http://www.salfordinsole.co.uk/"

casted orthosis another cast may sometimes be required. Owing to variations in casting technique, this will inevitably produce a different shape of cast and orthosis, which may not be as effective as the original.

Many will argue that prefabricated orthoses do not lend themselves to accurate modification, such as the addition of wedge material under the heel or forefoot, so that the precise biomechanics of the foot can be altered. In fact, many prefabricated orthoses are supplied with such additions ready for the clinician to use. Those that do not will often accept ethyl vinyl acetate (EVA) or other materials being adhered to the base of the orthosis.

Some argue that casted orthoses are the only means to achieve appropriate correction or control of foot motion. There are several counter arguments. First, a foot orthosis is used as a means of achieving successful clinical rather than biomechanical outcomes. The biomechanical alteration that occurs is a means to an end, not an end in itself. Second, there is little evidence of precisely what 'ideal' or 'better' foot biomechanics is, so it is not clear what the mechanical goal for the orthosis should be. Third, there is very little evidence to suggest that an orthosis, which matches the shape of the foot when casted, offers any specific clinical benefits over a prefabricated orthosis. However, there is evidence that orthoses of all types (including sham and orthoses that are almost placebo in design and effect) lead to improvements in symptoms, and this outcome, rather than the biomechanical outcome, should remain the priority.

***Key** Concept*

A foot orthosis is used as a means of achieving successful clinical rather than biomechanical outcomes. The biomechanical alteration that occurs is a means to an end, not an end in itself, and should be a secondary clinical concern.

Casted foot orthoses

The comments made about the merits of prefabricated foot orthoses should not be read to mean that orthoses made from a cast of the foot are never necessary: they are. The exception to rule regarding routine use of prefabricated rather than bespoke orthoses is the foot with a known structural deformity, which will not be adequately accommodated by any prefabricated orthosis. This deformity may be the result of disease, such as Charcot-Marie-Tooth, Charcot changes or advanced rheumatoid foot disease, or prior traumatic injury. It might also be the case that a patient has a foot structure that is at the extremes of normal variation, and therefore using an off-the-shelf orthosis (which is designed close to an average foot shape) is not advocated. Casted orthoses do offer the opportunity to completely tailor the choice of materials for the patient, which can be critical in cases of diabetes and other at risk feet.

Overall, the clinical and biomechanical effects of casted and prefabricated orthoses are likely very comparable in the general population; and other factors dictate their use, such as cost and time. For the at risk foot, the use of casted orthoses is more easily justified given the consequences of high loading on specific sites of the foot. Even then, however, there are ample prefabricated orthoses available in many cases, and the expense of casted orthoses should be left to those patients whose foot health poses a significant clinical challenge.

'Which orthosis type is best?'

This is a common question but there is no simple answer; indeed, it is the wrong question to ask. The pertinent question is, 'Which shape and material of foot orthosis works best for this specific patient?' In most cases, a prefabricated orthosis can be found that offers appropriate clinical outcomes.

It is critical when evaluating evidence relating to the efficacy of foot orthoses that conclusions are not incorrectly extrapolated to all orthoses of a similar design. Evidence that one specific casted orthosis is better at controlling pronation of the foot is not evidence that all casted orthoses perform this function better than prefabricated orthoses. The data relate only to the specific orthosis tested. A different casted orthosis could have the opposite result when compared with an alternative prefabricated orthosis. So, do not attempt to classify your practice by the manufacture method of 'type' of orthosis, but rather consider which orthosis offers what you decide each patient requires.

Importance of the flex line in the forefoot

If a full-length foot orthosis is chosen, it is critical to ensure that the forefoot area, especially the medial/lateral line where the forefoot flexes in gait, is not so stiff that it prevents sufficient dorsiflexion of the toes. A stiff forefoot area will resist toe dorsiflexion and could have significant effects on gait. The patient may attempt to obtain the required 'dorsiflexion', or rather forward motion of their centre of mass, from elsewhere, such as the knee or hip. Alternatively, they may simply lift their foot off the ground vertically and much earlier, resulting in a rather apropulsive and inefficient gait. If the material is very stiff, it is also likely to elevate forefoot plantar pressures. As a general rule, the forefoot area should be more flexible than the sole unit of the footwear the patient is wearing, assuming the footwear is deemed suitable.

There may be occasions when reducing toe dorsiflexion is advantageous, for example in cases of painful dorsal osteophytes or metatarsal head capsule pain. This is best achieved using a stiff sole unit on the footwear rather than a stiff orthosis.

Biomechanical objectives of foot orthoses

Foot orthoses are used for a wide range of clinical symptoms but underlying these symptoms are three biomechanical objectives:

1. To alter foot motion.
2. To alter stress experienced by internal hard and soft tissues.
3. To alter the distribution and magnitude of load applied to the plantar surface.

These are highly interdependent objectives. By influencing the movement of the foot as it contacts the ground, bears load and pushes off from the ground into the next step, a foot orthosis can influence the end position and range of motion of specific joints in the foot. These will impact on the precise orientation of bones relative to each other and orientation of the foot relative to the supporting surface. Through these changes a series of other biomechanical effects might be expected. The size and shape of the contact area between two articulating bones will change, and the stress experienced by ligaments and joint capsule structures, which stretch as the joint moves, will be affected. Not reaching the absolute end range of motion at a joint is likely to place less stress on passive ligamentous structures and the joint capsule, whose purpose is to resist motion, reducing the potential for ligament and capsular damage. Any increase in the

contact area between two bones is likely to mean lower peak loads at the articular surfaces, which will be associated with reduced risk of cartilage and subchondral bone damage, the precursors of arthritic changes.

A smaller range of motion at a joint will reduce the displacement required of a particular foot or leg tendon that helps control motion at that joint. This in turn may influence the extent of muscle shortening and the characteristics of the muscle contraction. Reduced foot motion will also impact on the velocity of foot bone movements and this in turn influences the velocity of tendon movement and muscle action required. A change in the position of a foot joint may change the muscle/tendon length at which muscle contraction occurs, and subsequently the efficiency of how the muscle generates the required forces. This may change the physiological effort required from the muscle and there is the risk that this effort lies outside the muscle's physiological range. Changes in joint motion velocity or displacement may be associated with reduced risk of injury as forces and the rates of loading of some muscle, tendon and ligamentous tissues are also likely to be lower.

The pressure exerted on a specific site under the foot has a strong association with sites of skin lesions, foot pain and plantar ulceration. Pressure is a function of both the load (force) applied to the area and the area over which the force is applied. Pressure can thus be reduced by increasing contact area, reducing the force applied to the area, or both. The forces under the foot can be redistributed away from areas of high pressure to areas of lower or no load simply by increasing the contact area between the footwear and foot with an orthosis. The use of an arch support on the medial side of an orthosis will enable the medial arch of the foot to bear load where it might not otherwise do so. The use of soft deformable materials enables an orthosis to conform to the shape of the metatarsal heads or other bony prominences, increasing the contact area at these specific sites.

Thus orthosis shape and materials can quickly increase contact area and reduce pressures experienced by the plantar surface of the foot. This type of foot orthosis is often termed a 'total contact' foot orthosis (Figure 3.3) and is made to a positive plaster of Paris cast of the foot that has not been modified in any way, which encourages distribution of load over the entire plantar aspect of the foot. This cast is made from an impression of the plantar aspect of the foot, often taken in foam (Figure 3.4).

Material properties are also critical in determining the pressure experienced by the foot. The use of thick, deformable materials will reduce the magnitude of loads applied to the foot and the rate at which load is

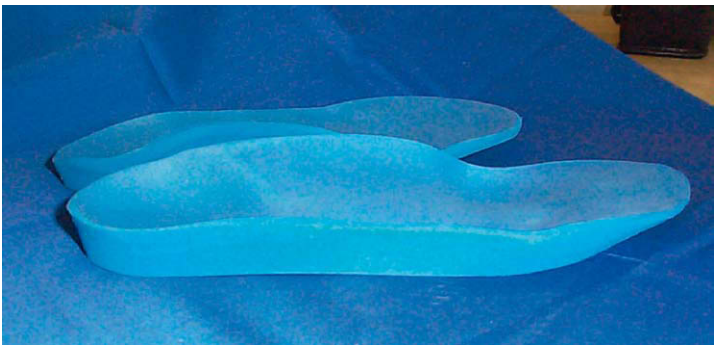

Figure 3.3 Total contact orthoses

Figure 3.4 Negative foot impression for the manufacture of a total contact foot orthosis

applied, both beneficial effects. When coupled with an increase in the contact area between foot and footwear (using an orthosis), cushioning materials can be very effective in reducing foot pressures. Recent work has shown how combining knowledge of both foot shape and foot pressure distribution (contact pattern) to inform orthotic design can provide improved reductions in plantar pressure compared with orthoses designed using only foot shape (Owings et al 2008).

How load is distributed under the foot, and thus which sites experience high pressures, is clearly related to the movement and position of the foot. A pronated foot will tend to distribute load more medially under the forefoot. This will load the first metatarsal head the most and, depending upon its ability to dorsiflex in response to the increased load, could result in very high metatarsal head loads. If the first metatarsal is able to dorsiflex under the load applied to its plantar surface, this dorsiflexion may reduce the loads at this site but cause the second metatarsal head to bear more load. The second metatarsal is less mobile than the first and is unlikely to be able to dorsiflex to the same degree, and thus will be subjected to high load. Likewise for the fourth and fifth metatarsal heads in a foot which adopts a supinated position and bears more load on the lateral side of the forefoot: the fifth will bear the majority of the load but may dorsiflex to such an extent that the load is redistributed to the less mobile fourth metatarsal head.

Thus, intra-articular joint contact area and pressures, the magnitude, timing and speed of forces experienced by ligaments, joint capsules, tendons and muscles, and the contact area, magnitude and timing of loading of specific sites under the foot can all be affected by use of foot orthoses. These effects underpin the theoretical basis of foot orthosis practice but in many cases are difficult or impossible to measure with current techniques. They are highly interdependent and this means that studying the biomechanical effects of foot orthoses to better understand their precise mechanisms of action is very complex. While we have many reports on the effects of orthoses in the literature, explaining variation between people in their clinical and biomechanical response eludes us.

It should be remembered that the foot is the interface between the rest of the lower limb (and body) above and the floor below. As such, changes in its function and mechanical behaviour will inevitably influence the mechanics of the knee, hip and more proximal segments. Transverse plane motion of the tibia (shank) is coupled with foot pronation and supination and so changes foot motion will influence tibial transverse plane rotation and thus may affect knee and hip biomechanics. It follows that the biomechanical behaviour of these structures can also influence the foot, and therefore the response to a specific orthotic intervention.

Controlling pronation of the foot

Changing the pronation movement of the foot is reported to have consistent clinical benefits for those with heel pain, shin splints, Achilles tendon

pain, first metatarsal phalangeal joint pain, anterior knee pain, iliotibial band syndrome and other musculoskeletal injuries. This is not to suggest that pronation is the causative factor in all these cases, but pronation movement is often one of a number of factors implicated, and changing one factor affecting the injured structure can produce good clinical results in a short period of time.

Three aspects of orthotic design are critical to controlling pronation of the foot. The biomechanical objective is to increase the supinatory moments acting at the combined ankle, subtalar and tarsal joints such that the pronatory moments that are causing pronation of the foot are resisted. This increased resistance to pronation will mean that the foot either stops pronating earlier, stops pronating with the foot in a less pronated position, or pronates more slowly than without an orthosis.

It is important to note that an orthosis will not and should not prevent pronation of the foot entirely, as this could have dire consequences for efficient and injury-free gait. In terms of effect size, an orthosis should rarely reduce pronation by more than 30 per cent, and clinical benefits can be observed even in cases when only very minor reductions in pronation occur. Many would consider a 10–20 per cent reduction to be a reasonable target.

Achieving this biomechanical objective involves the use of material under the heel to increase inversion moments at the rearfoot, and arch supports to prevent the tarsal joints dorsiflexing (and thus the medial and lateral arches lowering). These heel and tarsal effects are entirely coupled mechanically and thus this is a dual approach to controlling the same event: collapse of the medial longitudinal arch of the foot.

At the heel the orthosis should cup the calcaneus both underneath and at the sides of the heel. This reduces the space available in the shoe for heel movement and so can help resist heel eversion (which is a key visible feature of pronation). A wedge of material, with the thick part of the wedge under the medial side of the heel, can be used to increase loading on the medial plantar aspect of the calcaneus. This can increase the inversion moment under the heel significantly and be a powerful means of reducing the amount of heel eversion (Figure 3.5) and thus resisting pronation of the foot.

In the area of the medial longitudinal arch, many clinicians become very focused on the height of the arch support. This is important but so too are the point at which the arch support starts and the location of the highest point on the arch support. Ideally, the arch support should begin two-thirds of the way between the plantar calcaneal tubercle and the

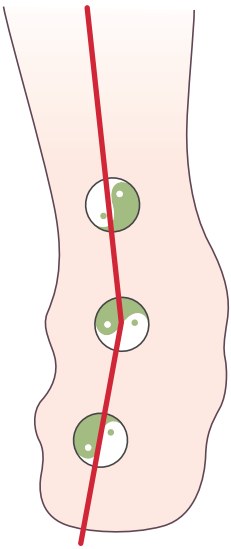

Figure 3.5 Heel eversion as a component of pronation

sustentaculum tali, rising up underneath the sustentaculum tali to directly oppose eversion. The vertical peak in arch height should be close to the talonavicular joint, which is highly mobile and a central feature of lowering of the medial arch of the foot. The arch support should continue anteriorly under the first metatarsal but cease proximal to the metatarsal head. This ensures there is sufficient room for the first metatarsal to plantarflex as the hallux dorsiflexes in late stance.

A less common but important consideration is the use of a lateral arch support. Between the calcaneus and fifth metatarsal head there is a subtle arch which is often neglected because it is far less visible than the more obvious medial arch of the foot. To truly maximize contact with and control of foot motion, however, all points of articulation should be addressed. A rise in the orthosis between the plantar calcaneal tubercle and the midshaft of the fifth metatarsal head will prevent the lateral arch lowering. Since all rear- and midfoot movements are coupled, neglecting this site can mean that good orthotic design features at the heel and

medial arch do not have the intended effect because the lateral arch has been allowed to continue to move.

In the frontal plane, the arch support should extend as far as the fourth metatarsal to fully support the tarsal structures. Recent research has demonstrated how significant tarsal and midfoot joints are in foot motion, often moving much more than the rearfoot joints (Lundgren et al 2008, Nester et al 2007). This means that in order to control foot motion, all the rear- and midfoot joints must be supported.

Reducing foot pressures and shear forces

Pressure is related to both the amount of force applied to the plantar side of the foot and the area over which that force is applied. Thus, to reduce the harmful effects of pressure at a specific site (area) under the foot, the biomechanical objective of the orthosis is either to reduce the magnitude or rate of application of force, or to increase the area over which that force is applied.

The total force applied to the foot is a function of body mass and acceleration of body mass relative to the ground, and, assuming both remain constant between strides, the same total force has to be applied to the plantar surface of the foot, regardless of the orthosis used.

Reducing the rate at which force is applied to the foot can be achieved using thick layers of soft cushioning materials. Thin layers of even the most cushioning materials can be ineffective if the forces applied are high. They will quickly compress completely ('bottom out') and become stiff under the foot. In contrast, single thick layers of material, or multiple thin layers, will deform under load but retain their compliance without becoming stiff and bottoming out.

In addition, it is likely that use of these conforming materials has important effects local to specific sites under the foot. For example, as a metatarsal head compresses an insole, the material deforms and conforms to the shape of the metatarsal head. As it conforms (adopts the same shape as the metatarsal head region), it will increase the contact area, thereby reducing the peak pressure at that site. Coupled with the reduced rate at which force is applied, this can be a very useful clinical effect.

As well as such 'local' changes in contact area, there are obviously possible gross changes in contact area. The use of a deep heel cup can ensure that the medial, lateral and posterior sides of the calcaneal fat pad bear load. The use of arch supports will increase the contact area under the foot as soon as the anterior aspect of the plantar surface of the heel is loaded. At the stage when the heel and forefoot are on the ground, the

medial arch will be able to bear a significant proportion of the force applied to the plantar surface, unloading the heel and potentially the forefoot, too. This benefit is lost as soon as the heel comes off the ground, because the orthosis under the arch of the foot will no longer be in contact with the ground. Figures 3.6 and 3.7 show that a rigid orthosis with only 1.8 mm of rigid material under the heel can still reduce heel pressures by up to 50 per cent at specific sites under the heel, simply by redistribution of load, and no shock absorption. Do not assume pressure reductions require soft and compliant materials.

It has been widely assumed that making a foot orthosis to the shape of the foot (using a cast) would provide the best means of maximizing contact area and thus reducing foot pressures under the forefoot. One difficulty with this is the fact that when pressures are greatest under the forefoot, the heel and midfoot are off the ground, so any arch support and heel cup that are created from the cast of the foot are largely ineffective in terms of increasing contact area at that point in the gait cycle. A further difficulty is that foot shape may not relate to the contact area between the plantar aspect of the foot and the shoe. Recent orthotic innovations have focused on the integration of foot shape information with pressure pattern (contact area pattern) data, and manufacturing the anterior edge of the arch and metatarsal head area according to the contact pattern rather than the foot shape. This has produced consistently greater reductions in foot pressures compared with orthoses based only on the shape of the foot (Owings et al 2008).

Perhaps the most effective pressure-reducing orthoses combine all these properties: a rigid arch support to redistribute load as much as possible, use of compliant materials under the forefoot to increase local contact area at the metatarsal heads, and reduce loading rates owing to their compliance. The positioning of these forefoot features must take account of the pattern of contact between foot and shoe.

It is thought that shear forces (sliding forces) are as damaging as vertical pressures under the foot and can lead to serious complications such as foot ulcers. Under the forefoot, shear stress is greatest during propulsion when the foot is pushing backwards against the ground. If the plantar skin is adhered to the sock and shoe then the shear forces may become concentrated within the soft tissues of the forefoot and cause tissue damage. To reduce shear forces under the forefoot, the forefoot must be allowed to slide backwards inside the shoe at this period of gait, so that the shear forces that are applied to the skin surface are reduced. However, a well fitted shoe will prevent this due to a strong heel counter, good arch support and appropriate lacing and throat. As with the pressure changes already mentioned, local changes in shear (that is, changes occurring

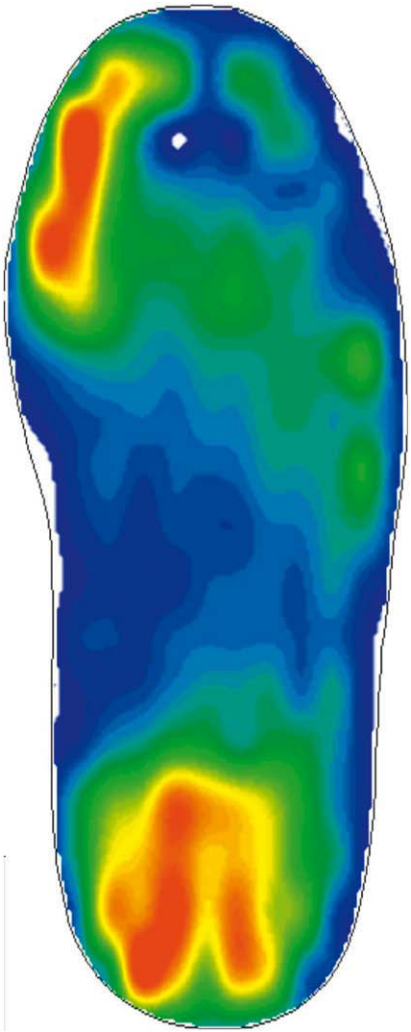

Figure 3.6 Foot pressure without orthosis. Salford insole HYPERLINK "http://www.salfordinsole.co.uk/"

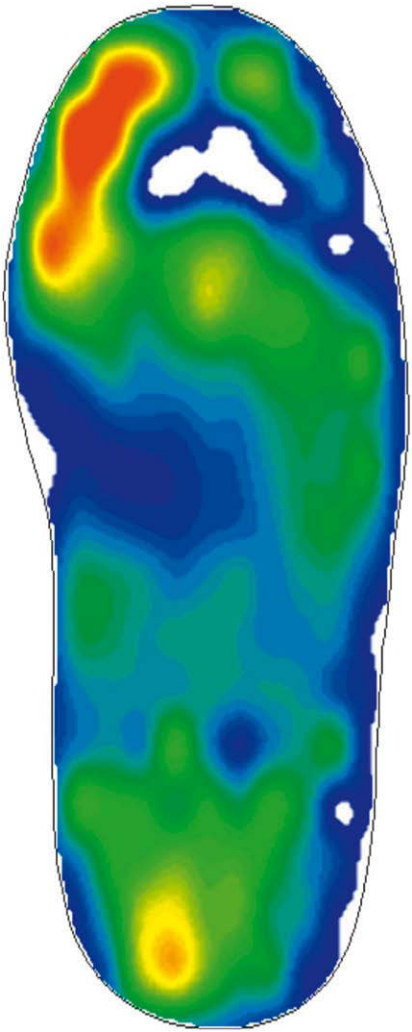

Figure 3.7 Foot pressure with foot orthosis – note increased contact in the arch and distal heel area due to the geometry of the insole, and subsequently lower heel pressures due to this redistribution of load. Salford insole HYPERLINK "http://www.salfordinsole.co.uk/"

local to a specific site on the foot, for example the metatarsal head) may be facilitated using a low-friction top cover on the orthosis. This may not need to be used across the entire orthosis surface, however, otherwise the heel and arch may slide within the orthosis in the early stages of stance, and the foot may adversely push against the sides or end of the shoe, increasing risk of injury at these sites. Reducing shear forces is complex and has yet to be properly resolved, and 'twin skin' hosiery (comprising two fine layers of cotton) perhaps offers the best solution at present.

Foot orthoses for medial compartment osteoarthritis of the knee

An increasingly popular strategy for managing pain associated with osteoarthritis in the medial compartment of the knee is the use of a lateral wedge under the foot. The desired biomechanical effect is to increase the eversion moments at the foot with the explicit intention that this will also increase the valgus moments at the knee (frontal plane moments). The net effect is a reduction in the varus moment acting at the knee, reduced varus angulation of the knee and redistribution of load from the medial to the lateral compartment of the knee. This is associated with reduced knee pain and it is postulated that even disease progression may be affected.

Some question the logic of deliberately pronating the foot, which may increase the risk of other forms of foot or lower limb problems, however, patients being treated in this way already have significant pain and often reduced mobility, and it is better to focus on these real symptoms and problems rather than on supposed problems that in fact may never manifest. Many patients who may benefit are on a well defined path towards knee replacement surgery, so there are very strong clinical and economic reasons for trying this orthotic strategy first. There are also few reports of complications from users, which perhaps says a lot about the role of pronation in causing foot problems. Finally, the most effective way to reduce the varus moment at the knee using this orthosis is to actually prevent the foot from pronating while at the same time applying a lateral wedge to the foot; thus, the foot does not necessarily pronate more than it otherwise would. Doing this means that the foot is unable to move in response to the increase in foot eversion moments created by the wedge, and, in principle, this should increase the expected biomechanical effect at the knee. The lateral wedge can be placed on the underside of the orthosis and must run from the heel to the fifth metatarsal head area. It can cover either the full width of the foot or only about half the plantar width. It is best suited to those patients with laced and flat or low-heeled

shoes, although in the face of significant knee pain and the prospect of surgery, many patients are willing to reconsider their footwear choices in order to accommodate the orthosis.

Foot orthoses for the at risk foot

Feet that are at risk of ulceration, infection and gangrene, and ultimately amputation, require particular care if orthoses are to be used to redistribute abnormal pressure and loading. The main groups of patients are those with high-risk foot disease associated with diabetes, peripheral vascular disease and advanced rheumatoid foot deformity. Additionally, patients with deformity associated with Charcot-Marie-Tooth disease (hereditary motor and sensory neuropathy) and spina bifida will fall under this category.

There are no unique objectives when using foot orthoses for the at risk foot, as the aim is still to control foot motion if the joints of the foot are flexible, and to reduce foot pressures; however, the implications of getting the prescription wrong are significant, if not catastrophic, and the role of footwear in orthosis choice becomes even more relevant. The benefits of a very thick orthosis to provide excellent plantar cushioning are negated if it forces the dorsal surface of the toes against the shoe upper. The use of a very rigid material for the *entire* orthosis should be avoided if the aim is to control heel and arch motion; instead, these rigid materials should be used under the heel and arch only, and a forefoot extension added using soft, compliant materials. The choice and siting of the forefoot layers, and additional padding such as domes, should be informed by the contact pattern under the foot, not just the shape of the foot. Footwear design features can further reduce foot pressure (rocker sole, stiff forefoot flex line, and high toe spring). It is also the case that monitoring the orthosis' performance and degradation over time is critical. This will tell you whether the orthosis is being used as often as it should be, and when it requires replacement or modification.

Foot orthoses for people with rheumatoid arthritis

Foot orthoses are provided to two main groups of patients with RA: those with foot problems associated with early disease and those with more established foot problems. There is an inextricable relationship between the foot, foot orthoses and the footwear that houses them both. The use of appropriate footwear (Williams et al 2007, Fransen and Edmonds 1997) in conjunction with foot orthoses has been recognized as minimizing the pain and disability associated with RA (Hodge et al 1999, MacSween

1999) when there is established foot deformity. The choice of foot orthoses in relation to design and function is dependent on the amount of motion in the joints of the foot. This factor is not dependent on disease duration as some patients with early disease have limited motion and some with longer disease duration have good range of motion within the joints of the foot.

There is the potential to prevent major functional and structural foot problems by providing foot orthoses early on in the disease process if joint mobility is still good; however, as foot changes have the potential to occur within two years of disease onset (Turner et al 2006), it is essential that patients be referred for assessment of foot function as early as possible following diagnosis.

***Key** Concept*

Those people with a diagnosis of RA should be assessed as soon as possible following diagnosis. Assessment of structural problems of the lower limb and foot, and provision of appropriate foot orthoses and footwear advice/specialist footwear, is important in reducing pain and stabilizing the foot. This may ultimately reduce deformity.

Once the structural problems are established and joint mobility is reduced, management consists of reducing symptoms of pain and resultant mobility problems. Further to this, redistributing foot pressures may contribute to the prevention of tissue breakdown and ulceration over high-pressure areas of the foot. In reality, however, the choice of orthoses is governed by the suitability of the patient's footwear, which may not accommodate the ideal foot orthoses for their particular problem.

The benefits of foot orthoses (insoles) and footwear have been recognized and recommended by the NICE guideline 'Rheumatoid arthritis: the management of rheumatoid arthritis in adults' (2009), which recognizes the importance of these interventions, as indicated by the evidence for their effectiveness:

> *"Functional insoles and therapeutic footwear should be available for all people with RA if indicated."*
>
> NICE 2009

There are a broad range of devices which employ a variety of different approaches to modify foot and lower limb structure and function, resulting in the lack of a formal system of classification or prescribing algorithm. However, there is a general consensus within the services

providing them that foot orthoses for patients with RA include these main groups:

1. Simple cushioning insoles.
2. Insoles to which padding or other additions can be applied.
3. Contoured insoles intended to change the function of leg and foot joints, either:
   - custom made to a cast of the patient's foot, or
   - supplied off the shelf.

There is no formal classification of foot orthoses, but the clinical choice appears to be based on the degree of deformity, the symptoms and the ability of the patient's footwear to accommodate the orthoses. The boundaries between the modes of action of the types are not always exact and an individual device may include elements of more than one type or mode of action. Clark et al (2006) in their critical review of the literature concluded that there is limited and often conflicting evidence on which to base clinical practice. However, they further concluded that there are indications from the available research that:

- foot orthoses reduce pain and improve functional ability
- both hard and soft orthoses have the potential to reduce forefoot pain
- hard orthoses have the potential to reduce rearfoot pain in patients with early RA
- hard orthoses have the potential to reduce hallux abductovalgus.

The premise of simple cushioning insoles is that the addition of a compressible padded material under the weight-bearing surface of the foot can reduce symptoms and so improve comfort and function. In their simplest form, simple insoles comprise one or more flat layers of compressible material that provides a softer interface than that normally found inside the shoe.

Although simple insoles can provide some pressure reduction at the interface of the foot and shoe, where loads need to be modified more systematically (typically where the structure or function of the foot is altered in some way), modular additions can be added to the basic simple insole design. One of the more common modular additions is an arch 'filler' that aims to redistribute load away from the forefoot and is reported anecdotally to reduce symptoms. A similar principle underpins the use of a forefoot plantar metatarsal pad that is intended to support the transverse arch across the ball of the foot. Two small studies indicate that metatarsal 'dome' and 'bar' pads reduce mean peak plantar foot pressure

Figure 3.8 Improved foot posture with functional orthosis

by up to 21 per cent (bars) and 12 per cent (domes) (Jackson et al 2004, Hodge et al 1999).

Contoured (functional) orthoses aim to improve function and alignment in those people with mobility in the joints. They are particularly useful in patients with early diagnosis of RA. In this case there is an attempt not only to reduce pain but to maintain good foot function and hence structure while the foot is vulnerable to deformity due to the combination of the inflammatory process and abnormal mechanics. Woodburn et al (2002) demonstrated reduction in forefoot pain, increased mobility, and a sustained effect on foot posture in patients with early RA foot disease (Figure 3.8).

Customised accommodative orthoses (total contact orthoses) are particularly useful where there is limited or no joint mobility, such as in the established RA foot deformity, and where tissue viability is poor. These orthoses are often made from materials that also provide a cushioning effect, such as softer EVA, or with additional foam linings. Li et al (2000) demonstrated that reduction in foot pressure and load distribution during gait were lower in those with RA and foot orthoses when compared with healthy subjects. Forefoot and rearfoot pressures were decreased and midfoot pressures increased. MacSween et al (1999) and Kavlak et al (2003) found an increase in stride length and reduction in pain in those with more established foot disease when using accommodative foot orthoses.

In summary, rigid custom-made, functional foot orthoses are insoles designed to control joint motions in early RA disease. Functional foot orthoses have been shown to reduce foot pain in people with RA and also to slow the rate of progression of deformity around the heels and ankles of people with early RA (Woodburn et al 2003). In established disease, more passive approaches are used, with pressure-redistributing insoles known to improve comfort and improve function. Details of current orthotic treatments for the foot in RA have been provided in two systematic reviews (Clark et al 2006, Farrow et al 2005).

Foot orthoses for people with diabetes

In relation to the risk of ulceration, the NICE guideline (2004) classify the diabetic foot as:

- low current risk (normal sensation, palpable pulses)
- increased risk (neuropathy or absent pulses or other risk factors)
- high risk (neuropathy or absent pulses plus deformity or skin changes or previous ulcer)
- ulcerated foot.

The guideline identifies that those who are high risk, that is, those assessed as having neuropathy, or absent pulses plus deformity or skin changes or previous ulcer 'should be provided with insoles'. However, it does not specify what type of insoles (orthoses) should be provided.

It is generally thought that those who are considered as at risk should have their foot structure examined to identify minor alterations to bony alignment and joint mobility in order to detect areas that may be placed under excessive stress.

So, the two main groups of people with diabetes who would benefit from foot orthoses are those considered high risk (an essential part of management) and those considered at risk (a desirable part of management).

In respect of insole/orthotic design and choice of materials, there is no clear algorithm for the construction of optimal foot orthoses. In clinical practice and in research, the choice of insole/orthosis tends to be based on what is to be considered appropriate for the foot deformity and the type of footwear. However, there is some research that supports the use of a variety of designs for the diabetic foot, mainly with the aim of reducing foot pressures. Guldemond et al (2007) reported up to 39 per cent reduction in pressure with flat insoles with additional arch supports and domes in patients with neuropathy. They found that a dome plus arch support reduced plantar pressure in the central and medial forefoot, concluding

that this seems to be the best choice for the construction of insoles. They also highlighted that insoles should be considered alongside footwear in the outcomes of this intervention.

Albert and Rinoie (1994) found that in patients with a pronated foot type, a custom-made foot orthosis can increase total contact area (redistribute force) and is able to reduce plantar pressures by up to 40 per cent under the first metatarsal head. Thus, an orthotic should reduce the risk of ulceration in the diabetic neuropathic foot, provided that the patient wears them (and the footwear that contains them) to a level that protects the foot, particularly during periods of high-impact activity or high levels of sustained activity. Further to this study, the effects of laterally and medially wedged foot orthoses may have additional effects on the passive and active soft tissues of the lower limb, and it is these changes that result in the documented clinical success.

There have been a number of studies that support reduction in foot pressures, describing a variety of orthosis designs and materials used in their construction. It has become accepted practice to provide total contact foot orthoses in a healing sandal as an alternative to a full walking cast in the management of foot ulceration (Figure 3.9).

A recent study (Fauli et al 2008) investigating the properties of polyurethane, ethyl vinyl acetate (EVA) and polyethylene identified that EVA and polyethylene foams within the low hardness range are the most

Figure 3.9 Total contact foot orthosis in a healing sandal

suitable materials for adaptation or accommodation applications, as they can conform to the foot and therefore reduce plantar pressures. Furthermore, they reduce the humidity produced inside the shoe and are perspiration resistant. In the harder ranges, they are more resilient to conforming pressures and therefore more suitable for controlling motion. If the materials are to be combined, then the authors recommend spot application of the adhesive so that the benefits of the humidity reduction are not reduced by a layer of adhesive.

Evidence base for foot orthoses

A detailed review of the evidence base for foot orthoses is not pertinent to this book. It is important, however, to recognize that research into foot orthoses is a growing activity internationally and there are excellent reviews of the evidence available in relation to the use of foot orthoses in specific clinical conditions.

In relation to rheumatoid arthritis, there are several important papers providing both biomechanical and clinical rationale that support the use of foot orthoses in established disease. It is logical that people with early disease may also benefit and an appropriate orthosis could provide a prophylactic effect. The type of orthoses used, however, may differ greatly in early and established disease, with the former aiming to support and help maintain normal foot structure and function, while the latter should accommodate any deformity and reduce pressures at vulnerable sites, particularly the forefoot.

In relation to diabetes, there is clear evidence of the value of customized orthoses but also that a patient-specific approach to design and material selection may be required. Depending upon the neurological and vascular status and footwear used, a range of deep, or motion-controlling, orthoses is advocated. There is evidence of the importance of correct selection of the material at the interface with the foot for improved pressure reduction, and the use of combined arch support and metatarsal domes or elevations to create a reduction in pressure in the order of 35 per cent or more.

Summary

Foot orthoses have the potential to reduce symptoms associated with many localized mechanical problems and those associated with systemic diseases. Further to this, they can improve function, mobility and a person's ability to carry out all the activities of daily living. In order for foot orthoses to be effective in achieving these benefits, clinicians need to be able to

choose the right design and materials. As there is an extricable relationship between the foot, the orthoses and the footwear that contains the two, footwear design and usage has a direct impact on the potential for the foot orthoses to be effective. The following chapters will provide the clinician with the knowledge and understanding that is required if we are to achieve the right combination of orthoses and footwear. Further to this, an understanding of the role of footwear as being more than protection is required if we, as clinicians, are to understand the impact of what we consider as an intervention and, from the patient's perspective, an item of clothing that is visible and can define who they are. This view of footwear has become established over centuries, therefore the next chapter gives a brief outline of the evolution of footwear design and purpose.

Review questions

Reflection

1. Can I provide a rationale for the benefits and limitations of bespoke versus off-the-shelf orthoses?
2. Do I understand the principle objectives of orthotic therapy?

Self-assessed questions

1. In what conditions is it desirable to control excessive pronation?
2. What percentage reduction in pronation is generally considered appropriate?
3. Describe the design of what is considered to be the most effective foot orthosis in reducing plantar pressure.
4. Why is the flex line of a full-length orthosis important in gait?
5. What type of device is useful in managing the symptoms associated with medial compartment osteoarthritis of the knee?
6. Describe the type and purpose of an orthosis for someone with early RA.
7. For which two main groups of patients with diabetes should foot orthoses be considered as part of the management of preventing foot ulceration?

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CHAPTER 4

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Evolution of footwear design and purpose

"The status of a man's shoe is an indicator of civilised values, economic well-being and impeccable taste."

Rev. Tom Foggy Dribble, 1825

Introduction

Footwear is much more than a protective wrapping for the feet. Although Riello and McNeil (2006) describe shoes as 'the principle intersection between the body and physical space' that allow us to move around our environments and experience the world in which we live, they also have a powerful influence on the social and emotional aspects of our lives. In this respect, footwear acquires different roles and has different meanings dependent on a person's taste, national and professional identity, social status, gender and sexual preferences. These meanings have manifested in different ways from the time of the ancient Egyptians and Greeks to pre-modern China and present-day Western societies. The purpose of this chapter is not to provide a detailed and comprehensive history of footwear, as there are whole books that focus on this subject; rather, the aim is to highlight to the practitioner how and why footwear became more than just a protective covering for the ancient Egyptians and Greeks. Thus, readers will understand that the social role of footwear

has become entrenched through the centuries, which has clear implications for our clinical practice.

***Key** Concept*

The issue of appropriateness of footwear needs to embrace the concept that it has to adapt to both the physical and the social environment. This issue is unavoidable as it has been present in society since footwear became more than protection in ancient Egyptian and Greek societies.

Origins and evolution of footwear design

The first footwear

Footwear is estimated to have started its long history of human use during the Ice Age, with unkind weather conditions being said to have created the necessity for footwear. Despite the fact that in Palaeolithic caves there were footprints of unshod feet, when Ötzi 'the Iceman' was discovered in the Tyrolean Alps in 1991, he was wearing footwear (Figure 4.1).

There is evidence that shows that the history of footwear started at the end of the Palaeolithic period, with paintings of this time in caves in Spain and in the south of France showing footwear dating from 24 000 years ago. That footwear was evident at this time is also supported by the work of Erik Trinkaus (2005) who noted morphological changes in the pedal phalanges resulting from either the presence or absence of footwear. Among the utensils constructed of rock found in Palaeolithic caves, there are several that were used to scrape the skins of animals, indicating that the art of tanning is very old. Early footwear was made of wrappings, usually made of leather or dried grasses. Later on, footwear developed to become an oval piece of leather that was bound by strong leather thongs.

The earliest footwear in Britain must have resembled the *pampootie* from the Aran Isles, Ireland. Very few early shoes have survived intact and although fragments of Bronze Age footwear have been found in excavations, there are not enough to determine styles. The purpose of footwear at this time could be considered to be totally functional and there is no evidence to suggest that it had a social role.

Roman footwear

> *"The reason the Romans built their great paved highways was because they had such inconvenient footwear."*
>
> *Charles de Montesquieu, French philosopher (1689–1755)*

Figure 4.1 Palaeolithic footwear

Despite this opinion, the Romans produced a variety of footwear styles that evolved as a result of their invasion of more northerly countries. They arrived in Britain wearing the military sandal, called the *caliga*, which exposed the toes, had a lattice-patterned upper, front lacing and a heavily nailed sole. This was suited to the Mediterranean climate, therefore more suitable styles evolved such as the *calceus* and the *gallica*, both of which had closed toes which were more suited to the British weather.

After the Romans left, Britain began producing its own styles, usually a closed-toe leather shoe with an oval or round toe shape. The ankle shoe was popular in the 9th century and was made as a turnshoe, which meant the separate upper and sole were thonged together inside out and then turned. These shoes were generally straight in shape and so could be worn on either foot.

Medieval footwear

Footwear styles continued to change during the medieval age. The sole and upper were no longer thonged but stitched together with thread, and the toe became a sharp point, known as a 'scorpion tail'. Shoes began to get longer in the 1320s and became known as 'pikes', 'crackowes' or 'poulaines'. The length of the toe area was an indication of status. The

king and his court had shoes with the longest toes. This style was not worn by women, indicating their lower social ranking. The ankle shoe remained popular. It was usually side-laced with three pairs of holes.

The pointed toe disappeared at the end of the Middle Ages and was replaced by round and square toe shapes. At first these toe shapes were a sensible size, but then became increasingly larger. During the reign of Henry VIII, the toe area reached 6½ inches with the footwear known as 'foot bags'. During this period came the widespread use of lasts, or as they were termed 'laests', although there has been some evidence that the Romans also used lasts on which to make their footwear.

18th-century footwear

In the 18th century, women's footwear reflected the elaborate patterns of their dresses and had similar embroidery and trimming (Figure 4.2).

Bands of metallic braid were popular as decoration on shoes. The silver or gold braid was transferred from one pair of shoes to another.

Figure 4.2 18th-century footwear

Other characteristics included pointed toes, ribbon and buckle latchet ties, and high covered wooden heels.

By the end of the 1760s, thick heels began to thin down and were therefore not very strong, the top became wider and more wedge-like, producing in the 1770s the 'Italian Heel' for women's shoes. Towards the end of the 18th century and the beginning of the 19th century, women's shoes became lower in cut and heels became lower until they disappeared altogether. The pointed toe was replaced first by narrow oval toes and then by square toes. Shoes became dainty, made from satin and silks to which ribbon ties were added to keep the shoe on the foot.

19th-century footwear

The 19th century is characterized by the predominance of boots both for men and women. Apart from boots, women wore 'court shoe' styles in a variety of different materials, from satin and silk to reptile and leathers. Men had a choice between the Oxford shoe (Figure 4.3) with front lacing and a closed tab, and the Derby shoe, with front lacing and an open toe.

Figure 4.3 Oxford shoe

20th-century footwear

The 20th century saw a variety of footwear styles and the rise to prominence of the shoe designer. Examples of footwear style include the 1920s' bar shoes, the 1940s' utility styles, the 1950s' brothel creepers, the winklepickers of the 1960s (Figure 4.4), stiletto heels (Figure 4.5) and the 1970s' platform soles. Shoe designers have been prominent throughout the 20th century, but the 1980s and 1990s have seen increasing success for shoe designers such as Patrick Cox, Manolo Blahnik, Emma Hope, Vivienne Westwood, Jeffery West and other notable designers, with their names being identified through their footwear styles and designs.

Extreme footwear has hit the headlines of national papers and TV news, such as the platform shoes by Vivienne Westwood (Figure 4.6) that

Figure 4.4 Winklepickers

Figure 4.5 Stiletto shoes

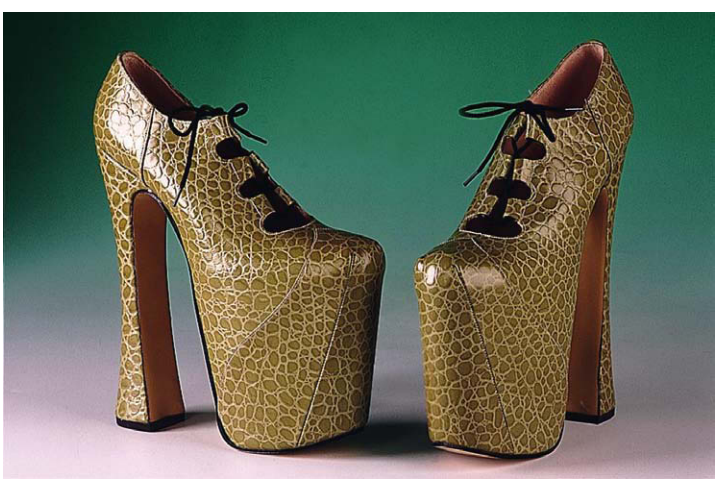

Figure 4.6 Platform shoes

caused the supermodel Naomi Campbell to fall on the catwalk. Platform shoes have evolved from the functional 'chopines' that were prevalent in the early 16th century, whose function was to raise skirts above the sewage that was present in the streets of that period.

The social role of footwear

Modern footwear design has clearly evolved over the centuries to have a purpose more than just foot protection. It has an additional purpose, and that is a social role. This role is evident even as early as ancient Egyptian times. In Egyptian funeral chambers, paintings show that footwear demonstrated power and class. The pharaohs' sandals were distinguished by their turned-up toes, a characteristic that is missing in the commoners' footwear. Egyptian sandals were crafted using straw, papyrus or palm fibre. Later on, the women of this period adorned their footwear with precious stones and jewels, with the footwear in this instance denoting class and gender.

Material evidence shows that the ancient Greeks loved and took good care of their feet by using different footwear for different activities. Greek women began wearing sandals to signify their social class. Their footwear also signified beauty, elegance, refinement and extravagance. It has been said that Greek women of ill repute attracted men by wearing elevated sandals. These sandals created a 'clacking' sound when the wearer moved, which was considered as a symbolic flaunting of sexual charms. Maybe this symbolism is still evident today in the clicking of high-heeled shoes.

The smallness of women's feet has been emphasized by many cultures over the years, for example, in the French court, ladies' toes peeped out from under their skirts, giving the impression of small feet. The most classic example of social pressure for women to have small feet, which some consider a barbaric custom, was in pre-modern China, where women's feet were bound (Figure 4.7). This was considered important in Chinese culture at that time as it denoted the female role as being different to that of the male. The smallness of the foot made walking more sinuous but also more difficult. It clearly implied that the feet of men were organs of locomotion but the feet of women were part of their sensuous appeal. It could also be said that this custom reflected the male-dominated society.

If women in earlier societies encountered barriers against free movement, such barriers often had little to do with real bodily limits. The limits were social, and shoes played their role in constructing and reinforcing

Figure 4.7 Chinese footwear for bound feet

these roles. Even in modern society there is pressure to wear footwear that defines roles, gender and sexuality.

Body image and footwear

"Funny that a pair of really nice shoes make us feel good in our heads – at the extreme opposite end of our bodies."

Levende Waters (2009)

This statement by Levende Waters highlights that different styles of footwear can make us feel different about ourselves. In reference to the 'nice' shoes in this statement, the perception that certain styles of footwear are feminine or sexy appears to be inherent in many women. Perhaps this is the result of centuries of the focus on footwear as a reflection of social status and sexuality. Footwear is very much part of the image that we present to others. Footwear designs with high heels not only look different in themselves but they have an effect on the visual appearance of the body. They elongate the legs, plump up the calves, shorten the stride, and cause the back to arch, which in turn accentuates the bottom and overall creates what is perceived as a dainty walk that encourages a sexy 'wiggle'.

Conversely, with the emancipation of women and changing roles particularly during the World Wars, more manly or utilitarian shoes were

deemed more acceptable for fulfilling the roles that the women had to assume as their menfolk went to war. Additionally, it became more acceptable for women to wear trousers, deemed more practical. Although this move towards women wearing more manly clothes and shoes was for practical reasons, it has persisted in fashion trends with trousers and jeans.

Summary

Although the role of footwear is primarily as foot protection, it has evolved through the ages to be much more than that. It plays an important role in depicting a person's social role and in some instances their status. Further to this, it impacts on how we both look and feel about our appearance. It is crucial that practitioners understand the multiple roles of footwear when considering its influence on foot health, in foot management and when expecting their patients to change their footwear-wearing habits. This theme will be revisited in a later chapter in the context of the practitioner's assessment of footwear and the patient's footwear-wearing habits.

Review questions

Reflection

1. Do I consider the multiple roles that footwear plays when discussing footwear options with my patients?
2. What do I consider to be the main influences on footwear styles?

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CHAPTER 5

Modern footwear

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Introduction

Modern footwear has evolved with dramatic speed since the industrial revolution when automated production took over from the craft-based production of early footwear. This mass production has driven the variety of footwear designs that we have today, and the accessibility of cheaper footwear has resulted in an increase in the numbers of shoes owned by individuals. Changes in fashion are dealt with quickly and the automated processes allow adaptation of basic footwear designs.

This chapter will provide the practitioner with knowledge of footwear construction, design and the manufacturing process. The purpose of this is to achieve an understanding of the function of each component part in relation to the requirements for an individual's foot health. This is essential if the practitioner is to provide footwear advice to patients in relation to their footwear styles and purchases.

Footwear construction – component parts

The component parts of footwear can be grouped into those that make up the upper (the vamp, the quarters, throat, heel counter and toe cap), those which form the inner part of the shoe (insole and linings) and those which form the sole (shank, outer sole and heel) (Figure 5.1). The following areas are the main ones in relation to the fit of the footwear.

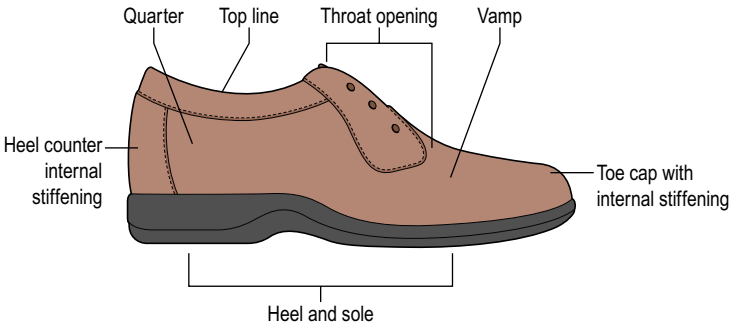

Figure 5.1 Parts of a shoe

Vamp

The upper is made of two main sections which together are moulded to form the upper of the shoe. The front section is termed the vamp and this covers the forefoot and the toes. In some shoe designs, the vamp can be decorative and made of more than one piece, or embellished with different materials or stitching. There may be problems with this area if the stitching and seams are too numerous, as these prevent stretching of the vamp material over the forefoot and toes and may lead to pressure on bony prominences. The vamp is usually reinforced in the toe area with a stiffer moulded material called a toe puff. This toe puff retains the shape of the front of the shoe and prevents it collapsing onto the toes. The toe puff can be made from a variety of materials including leather, manmade materials or, in the case of safety footwear, steel. In lace-up shoes and those with fastenings, the tongue of the shoe is attached to the vamp. The toe cap is a reinforcing cover stitched over the front of the vamp. It can be decorative in certain styles of shoe such as the brogue. In safety footwear there is a reinforcing and protective metal toe cap underneath the leather one.

***Key** Concept*

It is desirable for the vamp to be seamless with the toe puff supporting the front of the shoe so that the material does not collapse onto the toes.

Quarter

The sides and back of the upper are termed the quarters, and the top edge is termed the top line. The inner and outer sections of the top line

are often joined in the centre at the back of the heel. The inside of the quarter is usually reinforced around the heel with a stiffener called the heel counter, which has the purpose of stabilizing the rearfoot (particularly important in people with excessive foot pronation). In specialist footwear the heel counter can be extended medially and/or laterally to provide greater stability. In lace-up shoes the eyelets for the laces are at the front of the quarter and this part of the quarter covers the tongue, which is attached to, or forms part of, the vamp.

***Key** Concept*

A supportive heel counter is essential, particularly if the rearfoot requires support.

Throat

The position of this area of the shoe is dependent on the style. It is formed by the seam joining the vamp to the quarter. A lower throat line will provide a wider opening and is particularly useful in foot problems which require ease of access to the shoe, for example, rheumatoid arthritis. The seam will not stretch and therefore dictates the maximum width of the shoe.

***Key** Concept*

The throat of the shoe should open sufficiently for the foot to enter the shoe easily without discomfort.

Shank

The shank reinforces the middle or the waist of the shoe to prevent it collapsing or distorting. It therefore needs to be completely rigid or only slightly flexible, and is often made from wood, steel, plastic or carbon fibre. Shoes with a wedge sole or that are very flat do not need a shank.

Linings and insole

The linings are the inside of the vamp and quarter, and can be made of softer material than the upper; hence, they provide greater comfort and add to the durability of the footwear. The lining in the bottom of the shoe on top of the insole is sometimes termed the insock and can be full length or three-quarters long. The insole is the base inside of the shoe that covers the join between the upper and the sole. It is usually made from leather board but can also be made from material such as neoprene rubber to cushion the forefoot. It protects the foot from the shank.

Outer sole and heel

The under surface of the shoe can be made from a variety of materials and joined to the upper in several different ways, for example welted, stitched or adhesive applied. There should be a small amount of toe spring at the front part of the sole so that the foot does not catch the ground during walking.

The heel raises the rear part of the shoe above the ground. The height of the shoe dictates the pitch. If there is no raise at the heel area or the heel is lower than the sole, this is termed a negative heel. The material covering the area of the heel which contacts the ground is called the top piece, and this can be replaced or repaired.

***Key** Concept*

The design of the sole and the heel has an effect on function and needs to be considered if foot orthoses are being provided.

Materials used in footwear construction

Upper materials

Leather is the most common material and has the benefit of being permeable so that moisture can evaporate away from the foot. The advantage to foot health is that the skin is less macerated and it is therefore less likely that fungal infections will proliferate. Leather also stretches and accommodates to the uniqueness of the foot shape.

The advantages of leather can be negated by the use of synthetic linings and/or special coatings often used to protect the leather, or provide a special finish such as patent leather. Some modern synthetic materials are breathable, however, but often less supple than leather. The use of footwear with synthetic uppers should not be dismissed as long as they fit well and a suitable period of drying out is allowed between periods of use, but it is useful to remember that there is little stretch in this material, therefore footwear made from synthetic material may not be suitable for feet with prominences. Likewise, materials such as cotton corduroy may feel comfortable but stretch in only one direction and require reinforcement, particularly in the heel counter.

Linings

In traditional footwear the linings are usually made of soft leather or synthetic material. This does not generally cause a problem, as these are

usually confined to the quarters and the insock, where the lack of stretch and permeability are unimportant. Some modern lining materials can be breathable, wick moisture away from the foot or even be impregnated with silver, which is proven to be effective in reducing harmful bacteria.

***Key** Concept*

It is desirable that the linings be made of leather or another breathable material to allow moisture from the foot to be drawn away.

Soling and heels

The sole must be durable, waterproof and have sufficient friction to prevent slipping. Leather is the traditional soling material but is quick to wear out and can have poor grip. Manmade soling is more durable, resilient to water and can offer better grip, although this is dependent on the pattern of the soling materials. Soles can be made lighter through cavities in the main soling material being injected with lighter-weight foam. Combinations of materials can be used, such as a more durable layer outermost and a softer more flexible midsole for greater comfort. This can be a useful combination in patients presenting with foot pathology, foot pain and/or lesions associated with pressure.

The heel can be made from synthetic material or stacked layers of leather. The heel is covered with a top piece which can be replaced or repaired as the heel wears down with usage. The shank can be made of steel, wood or synthetic material. Toe puffs and stiffeners support the upper material and prevent it from collapsing onto the toe or inwards at the back of the shoe.

Footwear styles

Practitioners need to be aware of the variety of footwear styles and designs that suit different activities and levels of use. There are eight basic footwear styles, the rest being variations on the basic themes (Figure 5.2).

Although style is dictated by current fashion and the required function of the footwear, any shoe that is considered suitable for foot function and protection must have a mechanism for holding the foot back into the heel of the shoe. Without this fixation, the foot is allowed to slip forward in the shoe and this can result in friction on the sole of the foot, the toes impacting the front of the shoe or, in the case of sandals, the toes overhang the front of the sole.

The two key components of any style of footwear are a fastening around the instep and corresponding support at the heel, which need to

Style	Description
Boot	Any footwear extending above the ankle. There are numerous designs and types for a variety of uses and made from a number of materials.
Clog	Footwear with no heel counter. The sole can be leather, synthetic or wood.
Lace-up	Any low-cut shoe fastened by lacings.
Monk	Similar to Derby shoes, but with a crossover section to fasten the quarters with a side buckle.
Moccasin	This used to be a simple one-piece hide held on with rawhide thongs. Today moccasins can be slippers (with soft suede sole) and the term also describes a style of casual shoe.
Mule	A backless shoe or slipper with or without a heel.
Sandal	An open shoe with the upper consisting of any decorative or functional arrangement of straps. A sandal designed for simple utility or casual wear or as a fashion shoe.
Court	Heeled shoes (various heights) with low-cut fronts and usually no fastening. Those with a low heel are termed pumps.

Figure 5.2 Footwear styles

be firm and fit closely to the contours of the foot in these locations. The fastening around the foot prevents it sliding forward and the corresponding support at the heel prevents it from slipping backwards and sideward; therefore, mules, clogs, sandals and court shoes may be seen as being unsuitable. The suitability of each of the main styles depends, however, on the exact styling, heel height, materials used and also, perhaps most importantly, the use for which a person will be wearing the footwear. For example, high-heeled court shoes may be worn with minimal risks to foot health in healthy individuals if they are worn for a very short time with little weight bearing. If these shoes were worn for a long walk in the countryside, they would not function well and the feet would certainly suffer. Generally, an increase in heel height will increase the pressure under the forefoot and this has to be a consideration for people who have forefoot pathology or compromised tissue viability that will be vulnerable to necrosis and ulceration when put under excessive pressure.

Manufacture of footwear

The manufacture of footwear consists of several stages, starting with the manufacture of the last. The patterns that form the blueprint of the upper of the footwear are then cut and used in the process of cutting the leather for the upper. 'Closing' involves attaching the pieces of the upper together before the next stage, which is attaching the upper around the last and attaching the sole and heel. The final stage is called finishing, which involves tidying up the shoe, polishing it and attaching laces.

Last manufacture

The last is the mould on which the shoe is made. The word 'last' is derived from the old Anglo-Saxon word 'laest', which means footprint or foot track. The last determines the fit and feel of the shoe as well as wear performance.

Last design and manufacture is an extremely skilled craft. The measurements of the last are related to volume rather than width and length, and in this respect a last is not an impression of a foot. This is to ensure good fit and also take into account the changing dimensions of the foot during movement. Traditionally a craft skill, modern methods of last construction involve CADCAM technology.

Traditionally, lasts were made of hardwoods (Figure 5.3), but they are now made mainly of plastic, which does not swell or shrink; metal lasts

Figure 5.3 Traditional hardwood lasts circa 1800, single wooden last 1930 and plastic lasts circa 1960

are used in some manufacturing processes. The last is not an exact replica of the foot, although some dimensions of the last do correspond closely to those of the foot – particularly the circumference around the metatarso-phalangeal joints. The design of the last is determined by the shoe manufacturer. For some retail shoe companies, many thousands of people are measured annually to make sure that the lasts produced by the company match the feet of the general population.

A model maker translates specifications into original models and then other sizes and widths are graded up or down from the original, but holding true to the last shape. There are over 30 measurements required in the construction of a modern last. Lasts can be straight, that is, the inner and outer borders are straight; or curved (flared), either in-flared or out-flared according to the design of the footwear.

The considerations made by the last maker include the foot movements, the manufacturing process, the intended population, the purpose of footwear and fashion design. The design and shape of the shoe are dependent on the shape of the last; for example, a last for a high-heeled shoe needs to be shorter than the foot for which it is being designed to compensate for the shortened equinus position in which the foot is held. A last for a court shoe will differ from the last required to make a lace-up shoe by having an extremely curved heel and shallow toe area in order for the shoe to stay on the foot. The distance between the ground and

the toe area of the last is called the toe spring and it varies dependent on the height of the heel. The heel pitch is the angle from the plantar heel to the ball of the foot and it increases with the height of the heel. The toe spring is often higher in high-heeled designs to counteract the increase in heel pitch. In some specialist therapeutic footwear, the toe spring is increased even with a low heel to create a rocker effect in the fore part of the foot, thereby reducing abnormal forces in this area and increasing ground clearance. This therapeutic effect of shoe design in specialist ranges is discussed in Chapter 7.

Pattern cutting

Sectional patterns are produced for the uppers, linings, insoles, heels, soles, stiffeners, backers and toe puffs. The lasting allowance is added to allow the component parts to be fixed to each other. The materials used in making the shoes are cut from these working patterns. Traditionally, these patterns were made from thick paper but now technology has advanced to the point of computer-generated patterns (Figure 5.4). The

Figure 5.4 Pattern making using CADCAM technology

manufacture of specialist therapeutic footwear is still very much a craft process, however, and paper patterns are still used by many manufacturers in this area.

Upper cutting

There is an art to cutting leather, owing to the nature of the material – in terms of grain, blemishes and tightness. This part of the process was traditionally called clicking because of the sound made by the cutting knives (Figure 5.5) as the shoemaker cut the leather. The cutting was done by hand, with curved hand knives or a beam press with shaped press knives, to the required pattern. More modern techniques use computerized and laser equipment for cutting the materials for the component parts of the footwear.

Figure 5.5 Traditional cutting knives

Closing

The sections or component parts of the uppers are counted, checked, matched and marked for identification. They are then pierced, punched, embossed or perforated, as the design dictates. The edges of these sections are skived so that there is no bulk when they are assembled together. They are then positioned with linings and sewn together in the process called closing. All the aesthetic coverings or modifications to the upper are carried out in this part of the process.

Lasting

Lasting is the part of the process that involves stretching the upper onto the last and attaching it at the bottom in a variety of ways, dependent on the style of the footwear. Strain is applied at different points on the upper to stretch it. All the stretch is taken out of leather during lasting, such that the shoe maintains the last shape. There are many different methods of attaching the sole to the upper, dependant on the style and the purpose of the footwear.

Finishing

Application of the final stains and polishes takes place before the shoes are quality checked and dispatched.

Summary

By understanding the individual parts, it can be seen that the manufacture of footwear is a complicated process, requiring a combination of art and precision engineering. It requires from 100 to 175 different operations to make an average shoe. Knowledge of this process and the component parts is crucial if practitioners are to provide information to patients about the aspects of footwear in relation to its suitability for good foot health and function.

Review questions

Reflection

1. Can I describe the component parts of a shoe?
2. Do I understand the function of the component parts of a shoe?

Self-assessed questions

1. Name the two parts of the upper.
2. What is the structure which supports the waist of the shoe?
3. What is the purpose of toe spring?
4. Why is leather often used for the uppers of footwear?
5. What is needed to increase the access to a shoe?

CHAPTER 6

Footwear assessment

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Introduction

Footwear plays an important role in the maintenance of foot health, in the structure and function of the growing foot, and in the healthy adult population. Additionally, it plays a vital role for people with systemic diseases affecting the health status of the lower limb. Patients with diabetes, rheumatoid arthritis (RA), connective tissue disorders, peripheral vascular disease and other conditions associated with compromised neurological status and poor tissue viability benefit from appropriate footwear. It is known that footwear can be a precipitating cause of trauma leading to lower extremity ulceration and amputation in people with diabetes (Striesow 1998, Uccioli et al 1995, Chantelau et al 1990). The benefits of appropriate footwear in patients with RA are reduction in pain and increased mobility (Williams et al 2007, Chalmers et al 2000, Fransen and Edmonds 1997, Michelson 1994). In the elderly population, it is recognized that inadequate footwear such as badly worn shoes or slippers contribute to the occurrence of falls (Koepsell et al 2004, Sherrington and Menz 2003), demonstrating the complex interplay between footwear, walking and balance; because of the potential impact of footwear in these specific patient groups, a separate chapter is devoted to exploring the issues and options for them (Chapter 9).

***Author** Note*

The relationship between the foot and footwear needs to be investigated in any patient presenting with diabetes, rheumatoid arthritis and other disorders that place the foot at risk of serious complications such as ulceration.

The relationship between the foot and footwear is a consideration that needs to be investigated by the healthcare practitioner in any patient presenting with foot problems. However, it is often neglected by practitioners and its assessment has not always been given the attention it deserves. Footwear assessment complements assessment of the locomotor system. This assessment is mostly carried out relying on barefoot observations and therefore footwear is often ignored. Footwear can reveal the way that the foot functions during every day activity while the foot is in the shoe, and is potentially the one single factor that influences foot health in a positive way. In some cases, changing the footwear can be the only intervention required.

***Key** Concept*

Changing the patient's footwear in some cases may be the only intervention that is required. This holds true for a range of pathologies.

Assessment of footwear can contribute to, or confirm, a diagnosis and therefore it is important that practitioners have the ability to effectively assess patients' presenting problems, footwear and, perhaps most importantly, patients' understanding and therefore the potential for behaviour change related to footwear use. Effective footwear assessment relies on the ability of the practitioner and the patient to differentiate a suitable from an unsuitable shoe in relation to foot health and specific patient requirements. Appropriate footwear is an essential part of the management of most of foot problems. The specific skills required by practitioners are a mix of technical knowledge and assessment skills, patient management and empowerment skills, and professional artistry.

To maximize the patient's potential for positive foot health, whatever the underlying foot problem, practitioners should possess the skills to:

1. Assess the fit and function of the footwear in relation to the diagnosed foot pathology.
2. Assess the fit and function of the footwear in relation to the management of each patient's specific problems.
3. Assess the patient's level of understanding and willingness to change or modify their behaviour in relation to footwear.
4. Direct the patient to the appropriate type and style of footwear.

Assessment of the patient's footwear – history of usage and preferences

As identified in Chapter 4, footwear has evolved from being merely a protection for the foot from the environment to being an important aspect of body image and social status. These two factors have become inherent in our footwear choices and therefore the habits associated with the wearing of footwear are often well established. It is often an emotive subject to discuss when it comes to assessing a patient's footwear. If, through this assessment, the practitioner deems the footwear unsuitable for the individual's foot health, patient-focused negotiating skills have to be used, rather than just informing the patient that their footwear choice is 'bad'. Supporting patients in changing their footwear wearing habits is covered in Chapter 9. However, it is important that the approach to the patient during assessment of their footwear be non-judgemental as this is pivotal in building and maintaining a concordant relationship with the patient. Patient preferences have to be respected as these may originate from choice or necessity, for example the choice of footwear for specific occupations.

It is important to ascertain if the footwear worn to the consultation is what is usually worn. In fact, for new patients it is often useful to request in the patient's appointment letter that they bring a selection of the footwear worn most frequently.

The structure of a footwear assessment can be tailored to suit the practitioner's style but there are certain aspects that must be covered. Some of these may already have been covered in the patient's general assessment but certainly all these aspects have relevance to not only assessment of, but also management through, footwear.

Patient assessment checklist

These are fundamental issues which need to be covered before the decision is made with regard to footwear as an intervention. Designing your own assessment form is recommended:

- Past and current medical history, medication-associated problems or complications.
- Medication and allergies.
- Social history.
- Patient's activities of daily living.
- Circulatory problems (including microvascular and macrovascular disease, oedema).

- Sensory loss.
- Foot pain and origin: ischaemic, arthritic, inflammatory, neuropathic.
- Measure pain (use Likert scale for walking, standing and at rest).
- Skin: tissue viability, ulcers, lesions, infections (presence of dressings).
- Suitability of hosiery.
- Suitability of current footwear including history of footwear usage and preferences; wear marks.
- Foot structure and function: overall shape, function, areas of increased pressure.
- Gait, function and mobility.
- Assessment of the need for functional or accommodative foot orthoses.
- Patient's understanding of the planned intervention and agreement.

As with any assessment, there needs to be a structured and systematic approach so that essential factors are not left out. It is important to ascertain the patient's shoe-wearing habits as the footwear that they wear to their clinical appointment may not be the footwear that is worn the majority of the time; for example, they may have to wear specialist protective footwear at work or they may be at home mostly and wear slippers the majority of the time. Also, footwear may be chosen specifically for the appointment as they know that their usual footwear would be deemed unsuitable by the practitioner. Information about when, where and how often shoes are bought can be very useful as a baseline for the assessment of footwear and for a foundation on which to build specific advice.

***Key** Concept*

Ascertain if the footwear worn to the consultation is that usually worn for the majority of the time.

It is important to ascertain the patient's footwear history, such as past successes, likes, dislikes and requirements for employment (for example, safety footwear). Other factors that can be tactfully explored here are the patient's financial circumstances and preferences regarding body image. Patient choice has to be respected by the practitioner and provides a foundation on which future changes in footwear habits can be based.

***Key** Concept*

Patient choice has to be respected by the practitioner and provides a foundation on which future changes in footwear habits can be based.

Footwear as an aid to diagnosis – wear marks

The footwear needs to be assessed with the patient walking and standing to evaluate how the patient functions with the footwear. This can be followed by an assessment of the unshod foot once the footwear has been removed. This time can also be used to check the ability of the patient to put on and take off their footwear, and the footwear can then be inspected further because it can reveal clues to aid diagnosis. It is useful to start with an evaluation of any wear marks or distortions.

***Key** Concept*

Footwear wear marks or distortions in the footwear may help confirm a diagnosis.

Evaluation of footwear wear marks is an important aspect of overall assessment, providing clues to the underlying problem in relation to foot function, structure and gait. As the wear pattern can be unique to each individual, it can provide vital information in the specialist field of forensic science (Vernon and McCourt 1999). As shoe wear patterns may be a record of the usual long-term activity of the foot, their assessment may provide insight to foot function and influencing factors. There are a multitude of influences on footwear wear patterns (Figure 6.1).

Influences on shoe wear

Assessment of the wear patterns of footwear involves observing the inside of the shoe, the upper and the soles. This may help confirm a diagnosis or reveal information about foot function (Vernon et al 2004).

Footwear of a traditional, all-leather construction provides the best source of useful information. The reasons for this are that this type of footwear is constructed to last for an extended period when compared with mass-produced high street fashion footwear, and that the wear characteristics of leather are such that the effects of dysfunction are recorded in a way that is easy to read, with the intensity of wear being clear. Wear on modern materials can be much more difficult to interpret.

Normal wear

Pressure under the sole of the shoe should be even, so no one part wears out excessively. Normal wear should occur at the lateral heel and medial central forefoot (Figure 6.2), following the normal pathway of the foot's centre of pressure. Normal heel wear spreads across the postero-lateral

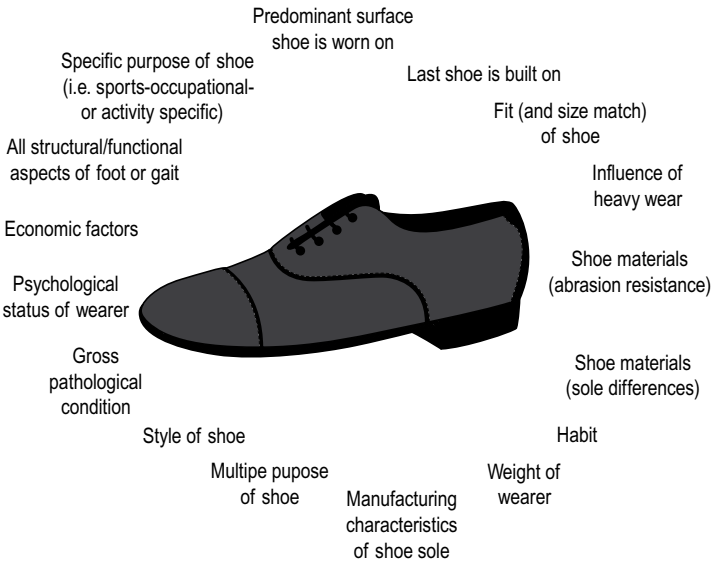
Predominant surface shoe is worn on
Specific purpose of shoe (i.e. sports-occupational- or activity specific)
Last shoe is built on
Fit (and size match) of shoe
All structural/functional aspects of foot or gait
Influence of heavy wear
Economic factors
Shoe materials (abrasion resistance)
Psychological status of wearer
Gross pathological condition
Shoe materials (sole differences)
Style of shoe
Habit
Multipe pupose of shoe
Weight of wearer
Manufacturing characteristics of shoe sole

Figure 6.1 Influences on footwear wear patterns (Vernon at al 2004). Reproduced with permission of Professor Wesley Vernon

border of the heel and this reflects the slightly inverted position of the heel at heel strike during the gait cycle.

There will be slight wear at the tread line of the sole in the region of the metatarsal heads and at the tip of the shoe. The wear occurring under the toes and at the tip should be minimal in relation to that at the heel and the tread line, taking into consideration the shoe as a whole. There should be no particular wear marks on the upper; in fact, the presence of friction damage to the upper is an indicator of either dysfunction or occupational or social factors, for example football-playing children. There is normally a crease along the vamp of the shoe which indicates the metatarso-phalangeal (MTP) joints and should coincide with the tread line. The heel area of the upper should be examined for distortion, with no bulging either medially or laterally, and the rear seam should be vertical.

Abnormal wear

Variations in wear occur for a variety of reasons but most of these indicate a problem in the way the foot functions. Among the causes of dysfunction are:

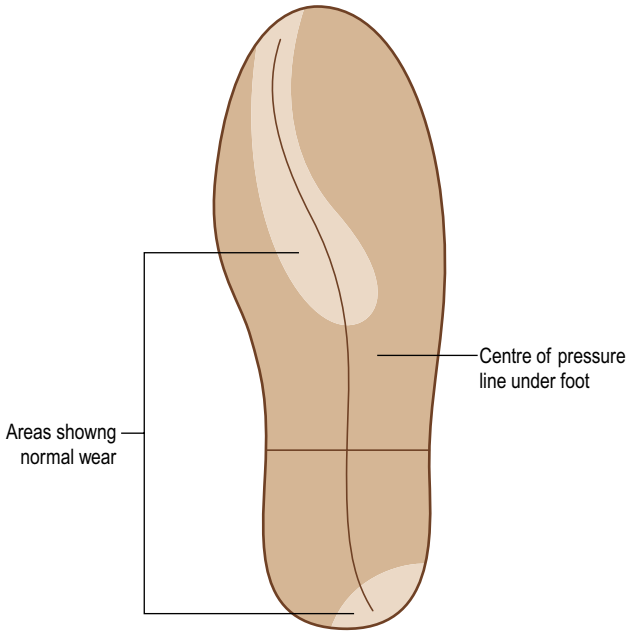

Figure 6.2 Normal wear marks in relation to the centre of pressure

1. Incomplete or abnormal ontogeny, resulting in bony architecture in which the foot is not plantigrade.
2. Abnormal pitch of any of the joint axes of the foot, producing abnormal movement in the foot.
3. Proximal abnormalities in the lower limb or trunk that result in abnormal position and hence function of the foot, for example, abnormal tibial or femoral torsion.
4. Feet that do not adhere to shoe manufacturers' concept of a foot that has normal dimensions, for example, a foot that has a disproportionately long heel to ball measurement compared with the ball to toe measurement will result in distortions.
5. Traumatic changes to any part of the locomotor system, resulting in abnormal function.
6. Disorders that affect the muscle control or bulk of the limb, affecting function, for example, cerebral palsy.
7. Poorly fitted footwear that inhibits or alters normal foot function.

There may very well be combinations of these factors, further complicating the issue.

Variation in heel wear

Normal heel wear is influenced by the fact that the heel strikes the ground approximately 2 degrees inverted as a component of normal late swing phase subtalar joint supination. The wear mark is to the lateral side of the posterior border of the heel.

If the foot is flexible and pronated throughout the gait cycle, the main heel wear mark will be along the outer border of the heel and may even move towards the medial side of the midline. This type of foot is so unstable that apropulsive gait is likely, with a consequent reduction in the severity of heel wear.

Excessive heel wear on the inner border indicates a rigid everted, pronated rearfoot. Conversely, excessive wear on the outer border indicates a rigid inverted rearfoot associated with a non-compensating rearfoot varus deformity. Heel strike in this case tends to be heavy and heel wear is more severe than usual.

Variation in tip wear

Excessive tip wear may occur for a number of reasons:

1. Loss of toe function because of forefoot instability, a cavus foot with retraction of the toes (that is, an excessively supinated foot) or extremely short footwear.
2. Uncompensated ankle equinus deformity.
3. Excessively long shoes.
4. Rigid soles with inadequate built-in toe spring.
5. Foot drop associated with anterior tibial muscle paresis or posterior calf muscle spasticity.

In addition there may be alteration in the position of the wear marks. This can occur more medially because of:

- excessive pronation during the propulsive period of gait
- a large angle of gait or
- hallux abducto valgus.

Conversely, more lateral wear on the tip can occur because the foot is excessively supinated, and is a feature of compensated forefoot valgus and primary plantar flexed first ray deformity.

Variation in tread line wear – rigid foot

A rigid foot may present for several reasons:

1. Developmental abnormalities that result in a need for compensatory supination of the foot, for example, rigid forefoot valgus.
2. Neurological pes cavus.
3. Iatrogenic rigidity following surgery.
4. The pitch of the midtarsal joint axis is so high that a forefoot supination contracture develops.

All these types will tend to produce excessive amounts of wear across the tread line of the shoe. This is because there is a lack of toe function owing to a combination of retraction and abducto-varus deformity. There is often no toe to ground contact and the metatarsal heads have to bear all the weight that would normally be assumed by the toes during propulsion. Additionally, a combination of excessively high metatarsal pitch and rigidity of the forefoot increases the stress under the metatarsal heads even further.

Under normal circumstances the treadline wear should be even across the sole, indicating approximately even weight bearing across the five metatarsal heads. In the rigid foot the exact position of the most severe wear will depend on the underlying cause of the functional rigidity.

In the majority of cases of pes cavus produced by neurological disease the wear across the tread will be over the first metatarsal head and the fifth metatarsal head. A similar pattern will be seen in a patient with a leg length difference on the supinating side. A subtle alteration will occur when the rigidity of function is the result of a forefoot valgus deformity that is compensating with subtalar joint supination. The residual midtarsal joint supination will sufficiently unlock the forefoot to destabilize the first ray and reduce its ability to bear weight. If the subtalar joint is functioning in a fixed position throughout the midstance period, there may be signs of an abductory twist under the fifth metatatarsal head, indicated by swirl marks.

Variation in tread line wear – severe functionally hypermobile pronated foot

With subtalar joint pronation, where the heel is everted and the midtarsal joint longitudinal axis is supinated, there is often fully compensated equinus. This results in similar wear patterns in the fore part of the shoe. There will be subtle variations in the severity of the wear pattern depending on the exact cause of the instability. The later that excessive pronation

occurs during the gait cycle and the longer it persists into the propulsive period, the more severe the wear over the anterior-medial aspect of the second metatarsal head. If instability is caused solely by midtarsal joint long axis supination, the wear will be almost entirely under the second metatarsal head. The clawing of the toes is an attempt to use muscle action to overcome the instability. This will increase the toe wear mark but because of the abnormal position of the apices, the mark will move more proximally. It should be noted that wear marks will only be present on the shoes of a propulsive foot and in the case of a hyperpronated foot there will be very little tread line wear.

***Key** Concept*

The 'hypermobility' referred to here relates to impaired functional stabilization, and not to benign joint hypermobility syndrome (or other connective tissue disorder) that causes generalized hypermobility.

Variation in tread line wear – mild functionally hypermobile foot

A mildly hypermobile foot, often the result of fully compensated rearfoot varus, produces only slight changes in treadline wear pattern with overload over the middle three metatarsals and possible overloading under the interphalangeal joint of the first toe caused by hallux limitus.

Distortion and wear of the uppers

In the individual whose foot is functioning normally, there will be little wear and distortion to the shoe upper other than a crease across the vamp that coincides with the tread line and the MTP joints.

Many of the frequently occurring variations in bony alignment of the foot result in function that impedes the normal plantarflexion of the first ray. This should occur during the propulsive period of the gait cycle but if it does not, is described as a functional hallux limitus since the hallux is unable to dorsiflex during the propulsive phase. This problem is more commonly associated with a fully compensated rearfoot varus. Additionally, as a result of the jamming of the first MTP joint, hyperextension of the terminal phalanx of the hallux occurs. The failure of dorsiflexion of the joint will often result in an alteration in the angle of the crease across the vamp of the shoe and the hyperextension of the toe may cause a visible bulge in the upper.

In the pes cavus or varus type of foot, there is generally some degree of supination contracture of the midtarsal oblique axis. This results in a

Excessive creasing in the upper
Medial bulge associated with hallux abducto-valgus
Distorted uppers associated with excessive pronation

Figure 6.3 Distorted uppers owing to excessive pronation

shortening of the medial border of the foot. The vamp crease will shift back on the medial side and will be nearly straight across the upper of the shoe. Additionally, there is almost always an associated retraction of the toes, which distorts the upper with bulges over most of the interphalangeal joints.

In the case where a person has severe and excessive pronation, the whole of the upper becomes distorted into a recognizable pattern. The combination of the changes is shown in Figure 6.3.

Distortion of uppers result in the life span of the shoe being shortened significantly. The most obvious distortion is the alteration at the throat of the shoe. This is caused by the adduction and plantarflexion of the talus with the medial shift of the navicular. These are the two major components of closed chain pronation. The medial heel bulge is caused by the third component of pronation, that is, the tilting of the calcaneus. The middle section of the shoe is markedly abducted in relation to the abnormal rearfoot position, appearing as a lateral break at the level of the midtarsal joint. The fore part of the shoe is broadened by the splaying of the forefoot, and the first and fifth metatarsal heads form prominent bulges. From the medial side, the most noticeable feature is the bulging of the upper caused by clawing of the toes.

Normally, adductus deformities are compensated for by subtalar pronation and these result in the wear patterns identified previously as being

associated with this foot type. However, if the foot is unable to compensate, the patient's gait will be adducted, resulting in characteristic scuff marks along the medial border of the upper from the heel counter through to the fore part of the upper and medial sole.

Heel counter wear and distortion

A normal heel counter seen from the back shows little distortion and wear. There will be mild lateral wear on the plantar aspect of the heel that is associated with the slight inversion of the normal foot during heel strike.

If excessive subtalar joint pronation is present when the heel strikes the ground, the heel counter will soon become distorted. The back seam will lean medially and there will be bulging over the medial border of the heel. The heel wear mark will be almost directly across the back of the heel. If the pronation does not take place until after heel strike, the heel wear will be normal but the upper will be distorted.

When the subtalar joint is supinated, the distortion will be opposite to the above, however, there will still be a bulge on the medial side as a result of the heel slipping across the heel seat at heel contact. The upper, outer, angle of the heel counter may be distorted by the presence of Haglund's deformity, which is an exostosis caused by compensatory movement associated with rearfoot varus. If the patient is overweight or has gross oedema, the heel bulge may be observed on both the medial and lateral borders, and classically the uppers are distorted in both directions, too.

Other factors influencing wear

Not all wear on shoes is the result of abnormal function. The most commonly seen occupational scuff mark is found on the back of the heel and is caused by driving. It is important to ascertain the patient's occupation and social activities in relation to their footwear as unusual wear marks can be misleading. As Vernon et al (2004) point out, shoe wear is a combination of a multitude of factors. Despite the acknowledgement that structural and functional variables are reflected in a variety of shoe wear patterns, there are other factors at play. These may be due to the footwear itself, that is, the materials, the design and the fit of the footwear. The type of activity that is inflicted on the shoes and the duration of this activity will have an impact on the amount of wear. These two factors are related to the extent of shoe wear, however, and not to the pattern of wear. Vernon et al (2004) state that identification of all these factors can aid diagnosis of the underlying foot pathologies in the context of the levels

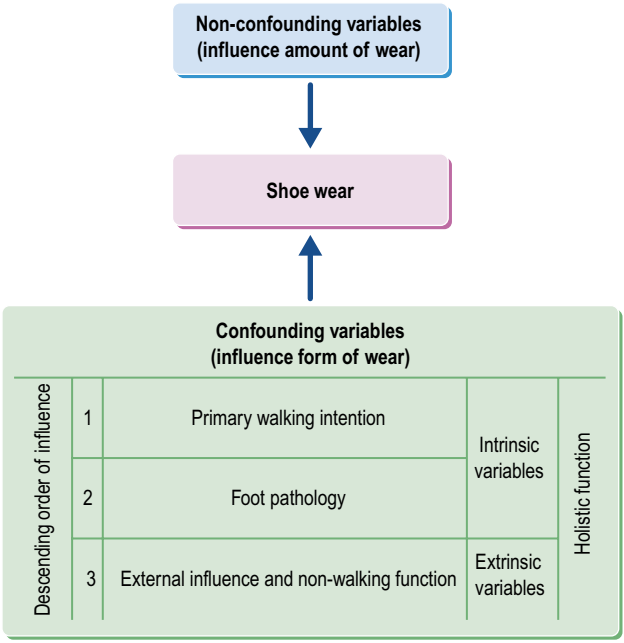

Figure 6.4 Model of shoe wear pattern influences (Vernon et al 2004). Reproduced with permission of Professor Wesley Vernon

of activity and the use to which the footwear is put, and this approach ensures that the holistic function of footwear is accounted for (Figure 6.4).

Essentially then, the 'one condition, one wear pattern' approach may have to be treated with caution as additional factors may well be at play in the resultant wear patterns and, unless these are considered as well, the correct diagnosis may be difficult to achieve.

***Key** Concept*

The 'one condition, one wear pattern' approach should be treated with caution as additional factors may well be at play in footwear wear patterns and unless these are considered as well, the correct diagnosis may be difficult to achieve.

Assessing foot size

Perhaps an obvious thing that the practitioner can do is to check the footwear is the right size in relation to the foot dimensions by measuring

the length and width of the foot. Other vital measurements are the heel to ball measurement and the depth of the footwear. Further aspects involve evaluating the fit at the heel, the access point at the throat of the shoe and the influence of the overall design on fit. A shoe size is a numerical indication of the fitting size of a shoe for a person. Several different shoe-size systems are used worldwide and with some regions using different shoe-size systems for different types of shoes (for example, men's, women's, children's, sport or safety shoes), they can be complicated and confusing. The following length units are commonly used today to define shoe-size systems:

- Barleycorn = ⅓ inch = 8.47 mm
- Paris point = 0.667 cm = 6.67 mm = 0.26 inch
- Millimetre (mm) = 0.039 inch
- Centimetre (cm) = 10 mm = 0.39 inch

There is an International Standard (ISO 9407:1991) of sizing and marking that recommends a shoe-size system known as Mondopoint. It is based on the mean foot length for which the shoe is suitable, measured in millimetres. A Mondopoint shoe label can optionally also specify the width of the foot, again in millimetres. A European standard (EN 13402) recommends instead that shoes should be labelled with the interval of foot lengths for which they are suitable, measured in centimetres.

The exact relationship between a labelled shoe size and the interval of foot lengths for which that shoe is suitable can vary substantially between different manufacturers. The following descriptions may only approximate the exact sizing systems used by individual manufacturers. One source of discrepancy occurs when a shoe manufactured according to one shoe-size system is labelled in another system. The various sizing systems can be seen in Table 6.1, denoted by country and also in inches, centimetres and Mondopoint.

Each shoe is suitable for a small interval of foot lengths. The length of the inner cavity of a shoe must typically be 15–20 mm longer than the length of the foot, but this relation varies between different types of shoes. There are three characteristic lengths to which a shoe-size system can refer:

- The average length of foot for which a shoe is suitable. For patients, this measure has the advantage of being directly related to their feet.
- The length of the inner cavity of the shoe.
- The length of the last.

Despite these measurements and sizes, it is up to the person fitting the shoes, whether they be a practitioner, a shoe fitter or a patient, to assess

Table 6.1 Sizing systems for footwear

International system		Sizes																
Europe		35	35½	36	37	37½	38	38½	39	40	41	42	43	44	45	46½	48½
Japan	Men's	21.5	22	22.5	23	23.5	24	24.5	25	25.5	26	26.5	27.5	28.5	29.5	30.5	31.5
	Women's	21	21.5	22	22.5	23	23.5	24	24.5	25	25.5	26	27	28	29	30	31
UK	Men's	3	3½	4	4½	5	5½	6	6½	7	7½	8	8½	10	11	12	13½
	Women's	2½	3	3½	4	4½	5	5½	6	6½	7	7½	8	9½	10½	11½	13
Australia	Men's	3	3½	4	4½	5	5½	6	6½	7	7½	8	8½	10	11	12	13½
	Women's	3½	4	4½	5	5½	6	6½	7	7½	8	8½	9	10½	11½	12½	14
USA and Canada	Men's	3½	4	4½	5	5½	6	6½	7	7½	8	8½	9	10½	11½	12½	14
	Women's	5	5½	6	6½	7	7½	8	8½	9	9½	10	10½	12	13	14	15½
Korea (mm)		228	231	235	238	241	245	248	251	254	257	260	267	273	279	286	292
Inches		9	9⅛	9¼	9⅜	9½	9⅝	9¾	9⅞	10	10⅛	10¼	10½	10¾	11	11¼	11½
Centimetres		22.8	23.1	23.5	23.8	24.1	24.5	24.8	25.1	25.4	25.7	26	26.7	27.3	27.9	28.6	29.2
Mondopoint		228	231	235	238	241	245	248	251	254	257	260	267	273	279	286	292

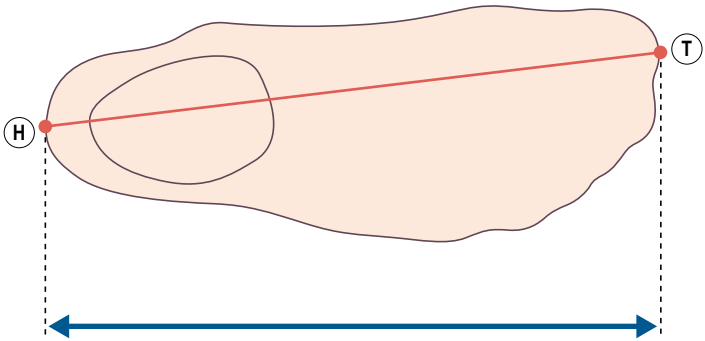

Figure 6.5 Overall length

the correct size of footwear as it does vary from style to style and from manufacturer to manufacturer. Essentially, shoe size is only a guide when it comes to choosing the right fit of shoe and the art of getting the fit right is much more than achieving the correct length of shoe.

Measuring overall length

Foot length is measured with the subject standing barefoot and the weight of the body equally distributed on both feet. The overall length of the foot (heel to toe) is measured from the back of the heel in the postero-plantar area [H] to the tip of the longest toe [T] (Figure 6.5), remembering that it may not be the first toe that is the longest. The sizes of the left and right foot are often slightly different. In order to choose a shoe size, both feet should be measured and then the shoe size should be chosen based on the larger foot.

An additional measurement of length, heel to ball (Figure 6.6), is very important in successful shoe fitting. Even if feet are the same length overall, the heel to ball measurement may vary. This measurement can be made to the middle of the width measurement but is more often measured to the first MTP joint. This has major implications for shoe fit and patient comfort. The first MTP joint must fit into the widest part of the shoe, which is designed to flex so that the shoe and foot can flex together. The practitioner must become proficient at determining the exact position of the first MTP joint inside the shoe because if it is too far forward or back, the shoe may appear to fit overall but will not be comfortable. The patient can be asked to stand on tiptoe and the flex line checked; or, if the shoe has a removable full-length lining, this can be used against the foot to check where the flex line occurs. If the MTP joint

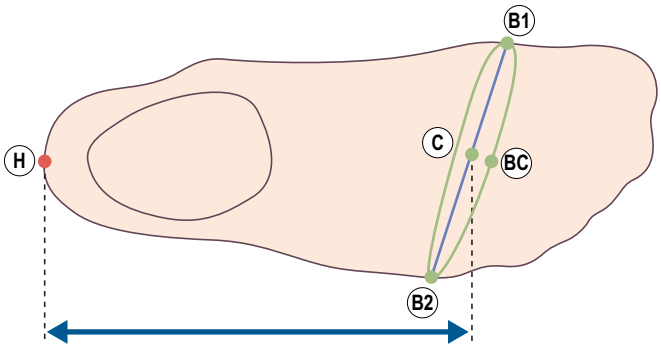

Figure 6.6 Length – heel to ball joint length. '[H = heel, B1 = ball at 1st MPJ, B2 = ball at 5th MPJ, C = circumference, BC = ball at mid circumference]

position is too far forward, the toes will be crowded in the toe box. If it is too far back, the result is abnormal tread wear marks and excessive creasing of the vamp. These measurements can be taken using a Brannock measuring device (Figure 6.7; see also http://www.brannock.com/) which provides the practitioner with more information than the traditional size stick. It provides a heel to ball joint measurement in addition to overall length and width.

***Key** Concept*

The heel to ball measurement is vital in choosing the right length of shoe overall, if the widest part of the foot (across the metatarsophalangeal joints) is to sit in the widest part of the shoe and along the flex line. If the heel to ball measurement is long in comparison with the overall length, such as in patients with retracted toes, the shoes will not fit or function correctly.

MTP joint to toe length

Check the length of all the toes and do not assume that the first toe is the longest. Generally, 1 cm space at the end of the toes is considered sufficient. Also remember toe width and forefoot shape in relation to the style of shoe.

Ball width

This is the width of the foot but, in relation to the footwear, includes the sole (ball tread) and insole as well as the upper. The shoe has to adapt to

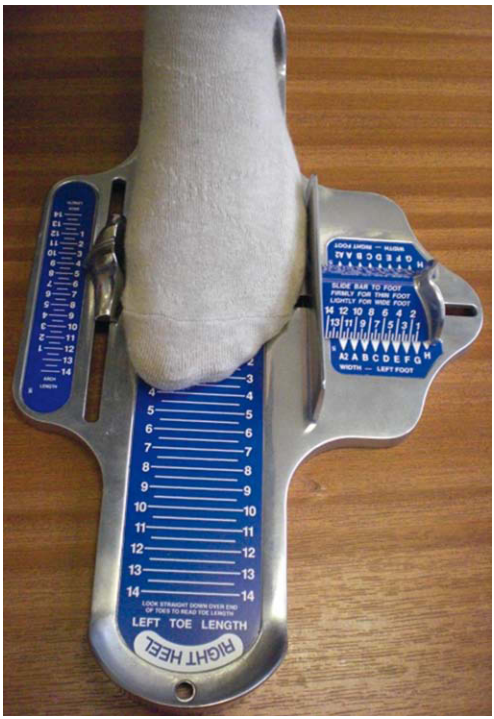

Figure 6.7 The Brannock device

three different widths at the ball, with the foot at rest, weight bearing and under thermal conditions, such as heat, which leads to swelling. Experience and judgement inform the practitioner which width will best suit all these conditions. Subjective feedback from the patient will also aid decisions.

Assessing footwear fit

Heel fit and heel height

The heel should be snugly cradled in the heel of the shoe to prevent gaping and slippage. The top edge of the heel counter should not dig into the Achilles tendon. Heel fit also influences the entire fit of the shoe because the foot has a different stance inside a high-heeled and a low-heeled shoe and also functions differently inside the shoe.

When walking barefoot, the heel of the foot is lifted about 5 cm with each step, with the ball of the foot working as a fulcrum for the step off. The amount of heel rise is proportional to the length of the step, therefore the longer the stride, the higher the heel rise. In a shoe with a 5 cm heel there is no rise in the heel because the shoe is already accounting for that rise. The higher the heel, the shorter the stride and body weight cannot shift from heel to ball as in barefoot walking but is concentrated wholly on the ball. In a flat-heeled shoe, the shoe and foot are functioning together with the heel lifting with each step and moving the weight forward onto the ball. In a low-heeled shoe, the vamp will crease with flexion of the forefoot. In a high-heeled shoe, there will be no creasing as there is no flexion of the MTP joint. The low-heeled shoe requires more toe room in the fitting because there is more forward movement, or extension, of the foot with each step.

Throat

This is the entry point into the vamp or forepart area. There must be sufficient room when the shoe is fastened onto the foot to allow for the waist and instep to move during weight bearing. A finger width at the back indicates sufficient room for this. A strong secure fastening to hold the rearfoot against the heel of the shoe prevents forward slide. The facings (where the eyelets are) should be usually 10–12 mm apart. If they are overlapping, the volume of the shoe is too much and if they are wider apart than 12 mm, the shoe is too small.

Design of patterns and vamps

The patterns that dictate the design of footwear have a tremendous influence on shoe fit. This applies especially to the ease of getting the shoe onto the foot and keeping it on securely. There are long and short vamp lasts and generally the rounder the toe, the more likely the vamp will be shorter; the more tapered the toe, the longer the vamp. Vamp length is determined by shoe design (especially in the retail industry) and correct style is crucial for forefoot comfort and fit. An example of a long and short pattern would be a six-eyelet tie and a three-eyelet tie style, each made on the same last. The difference in the patterns will affect the way the foot extends into the shoe and will also affect instep freedom. So, for example, where the practitioner would be fitting a shoe which is required to accommodate a large hallux valgus, a six-eyelet tie style would be a better choice as the throat entry would be larger, enabling easier entry and better adjustment of the top line around the foot.

Assessment of shoe fit is a combination of both objective and subjective factors as detailed in the Footwear Suitability Scale (Nancarrow 1999) (Table 6.2), which is a self-evaluation checklist that patients can use to check their own footwear. The Footwear Suitability Scale also provides a rationale that details why each aspect of the footwear is important. Although developed for patients with diabetes, it is useful for any person to check their footwear against. It is also useful for clinicians as a structured approach to checking footwear suitability.

Summary

Assessment of footwear is a crucial component of assessing a patient's foot health and should not be overlooked. Assessment of wear marks can aid diagnosis of foot pathology in relation to function and gait. To achieve this, a structured approach has been detailed that involves information on assessing foot size and assessing footwear fit. Footwear has to be suitable in relation to its design, fit and purpose, and these factors must be addressed when deciding if footwear is suitable for good foot health.

If the patient's existing footwear is deemed unsuitable, the practitioner needs to be able to direct the patient to the appropriate type and style of footwear. The next chapter deals with the options available to the patient and the practitioner.

Review questions

Reflection

1. How do I include footwear in patient assessment?
2. How do I assess the suitability of my patients' footwear?

Self-assessed questions

1. What are the two main reasons for assessing patients' footwear?
2. What are the main fitting points for checking the fit of footwear?
3. Describe the normal shoe wear pattern on the sole and heel.
4. Describe what happens to the foot with an increase in heel height.
5. Describe what happens with regard to shoe fit if the heel to ball joint measurement is long.
6. Describe the normal shoe wear pattern on the heel and sole.

Table 6.2 The Footwear Suitability Scale (Nancarrow 1999)

Check	Explanation	yes/no
1. Is the heel of your shoe less than 2.5 cm (1 in)?	As the height of your heel increases, the pressure under the ball of your foot becomes greater. Increased pressure can lead to callus and ulceration	
2. Does the shoe have laces, buckles or elastic to hold it onto your foot?	If you wear slip-on shoes with no restraining mechanism, your toes must curl up to hold the shoes on. This can cause the tops of your toes to rub on your shoes, leading to corns and calluses. Additionally, the muscles in your feet do not function as they should to help you walk; instead they are being used less efficiently to hold your shoes on	
3. Do you have 1 cm (approx. thumbnail length) of space between your longest toe and the end of your shoe when standing?	This is the best guide for the length of the shoe, as different manufacturers create shoes which are different sizes. Your toes should not touch the end of the shoe as this is likely to cause injury to the toes and place pressure on the toe nails	
4. Do your shoes have a well padded sole?	Shoes should have a supportive but cushioned sole to absorb any shock and reduce pressure under the feet	
5. Are your shoes made from material which breathes?	A warm, moist environment can harbour organisms such as those which cause fungal infections	
6. Do your shoes protect your feet from injury?	The main function of footwear is protection from the environment. Ensure your shoes are able to prevent entry of foreign objects which can injure the foot. If you have diabetes, a closed toe is essential to prevent injury to the foot	
7. Are your shoes the same shape as your feet?	Many shoes have pointed toes and cause friction over the tops of the toes, which can lead to corns, callus and ulceration. If you can see the outline of your toes imprinted on your shoes, then the shoe is probably the wrong shape for your foot	
8. Is the heel counter of your shoe firm?	Hold the sides of the heel of your shoe between the thumb and forefinger and try to push them together. If the heel compresses, it is too soft to give your foot support. The heel counter provides much of the support of the shoe and must be firm to press	

If you have not put a tick in every box, your footwear is probably not protecting and supporting your foot as it should do

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CHAPTER 7

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Footwear options

Introduction

There is a multitude of footwear options in relation to style, purpose and function. Patients often need to be guided as to the suitability of a range of footwear for different purposes. In addition to the generic factors in footwear design and fit that make a good shoe, it has to be acknowledged that there may be several others that are unique to the individual patient. In particular, when the foot's dimensions will not fit into retail footwear because of deformity or excessively abnormal function, specialist therapeutic footwear may be required. This footwear may be off-the-shelf specialist footwear that is often described as 'stock' footwear. However, if the foot problem is greater than can be accommodated in 'stock footwear', or if the mechanical needs are complex, then the footwear may have to be 'bespoke' and made on a last manufactured for the individual patient.

Retail footwear: 'What makes a good shoe?'

There are now many manufacturers of retail footwear who produce designs that are both appropriate for the foot health of our patients and affordable. Many foot problems benefit from a change in footwear style or to a style with different features. Some footwear can be modified with rocker soles, which are helpful in reducing forefoot pressures in the diabetic foot and pain and pressure in the rheumatoid foot.

In fact there are features of retail footwear that make it ideal for the high-risk foot but that are also useful for maintaining good foot health in any individual. These features are:

- stable heel: a heel that is broad enough for stability or elongated/flared to increase this effect further
- extended heel counter
- padded topline to reduce irritation to the retro-calcaneal area and the infra-malleolar areas
- no prominent internal seams
- winged toe puff
- increased toe spring or rocker sole to reduce forefoot plantar pressures
- low laced for ease of access.

Specialist therapeutic footwear

If patients have major foot problems or deformity, specialist therapeutic footwear can be provided through hospital appliance departments or orthotic services. Patients generally receive this footwear free of charge and they are entitled to two pairs at any given time which are repaired or replaced as appropriate when they wear out. Orthotists are the professionals who generally assess and provide this specialist footwear but increasingly podiatrists are working alongside their orthotist colleagues or taking on some of the orthotist's role, particularly in the provision of stock footwear. Teamworking in this area has demonstrated improved clinical outcomes and patient satisfaction compared with orthotists working in isolation (Williams and Meacher 2001). It is important that podiatrists create good working relationships with their orthotist colleagues in the assessment of patients, shared information and the provision of specialist footwear.

***Key** Concept*

Specialist therapeutic footwear can be provided through hospital appliance departments or orthotic services.

Stock

Stock footwear is specialist footwear which is available in a variety of styles and fittings, for example extra deep and/or extra wide (Figure 7.1). The manufacturers of this footwear provide size charts of optimal ranges for length, joint width, joint circumference and instep circumference, which are the measurements that are required to enable the practitioner

Figure 7.1 Stock therapeutic specialist footwear

to decide on the fitting of the footwear. Their choice may also be based on the style of the footwear in relation to function, for example the addition of rocker soles or extra padding. This footwear is generally supplied with 3 × 3 mm removable liners that can be replaced with orthotic devices. Often these liners are made from a shock-absorbing material such as memory foam.

Modular

This type of specialist footwear is essentially stock footwear that is modified to improve its overall fit to accommodate minor deformity or provide added stabilization. A trial fitting of the upper is often required before the footwear is completed with the sole and heel unit.

Bespoke

Bespoke footwear (Figures 7.2 and 7.3) is an option when there is major deformity, such as Charcot or advanced rheumatoid arthritis deformity, or if there is a huge difference in symmetry, fixed equinus of more than 20 mm, or if the foot dimensions are outside the measurement range for stock footwear. This footwear is made on a last specifically created for the individual, and often requires a plaster cast to be taken so that the footwear technician can visualize the problems and capture the

Figure 7.2 Bespoke footwear at trial fitting stage

Figure 7.3 Bespoke footwear – completed with rocker sole

dimensions of the lower leg and foot. Many measurements of the foot are required and these are recorded on a draft with instructions for the technician. This is very much a craft skill and is slowly being replaced with scanning technology and the use of CADCAM in the manufacture of both the lasts and the bespoke footwear.

Adaptations

Normal pain-free gait is achieved by the systematic and coordinated activity of the foot and lower limb muscles and bones. Both the alignment and function of the bones of the foot play a role in aligning the joints of the lower limb, and they also influence the positioning and function of the knees, hips, back, arms and neck throughout the gait cycle. How the foot is held within footwear and the footwear design itself can have a significant effect on the biomechanics of the lower limb and upper body. Footwear and/or orthoses can play a valuable role in modifying the position of the foot and limb and provide functional control through realigning and stabilizing the limb during gait.

Adaptations to the heel and sole unit can enhance and complement orthotic therapy, reduce excessive and abnormal wear of the footwear, reduce painful symptoms and improve the patient's function and mobility.

Flares, floats and wedges

These are helpful in patients with excessive mobility in the joints of the foot, where stabilization and control are required. Conversely, if the foot is fixed in a pronated or supinated position, heel and/or sole wedging may be needed to bring the ground up to meet the foot and prevent instability. A wedge of material can be inserted between the soling unit and the uppers or added externally to the shoe (Figure 7.4).

A medial heel wedge may complement orthotic therapy in cases of severe pes planovalgus, however, a wedge of more than 6 mm may negate the benefits as it will cause the foot to slide within the shoe.

A lateral extension to the heel area of the sole is used to increase the eversion moments acting at the rearfoot. The flare changes the initial contact point between the floor and foot, moving it further lateral relative

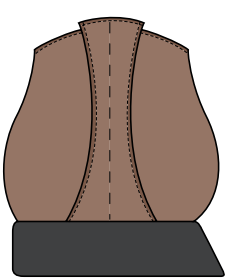

Figure 7.4 Lateral heel float

to the foot. This increases the moment arm relative to the rearfoot joints and thus the eversion at the rearfoot.

The flare may be used as an alternative to a lateral wedged insole to reduce knee varus moments and thus loading in the medial knee compartment, however, it is more unsightly than the foot orthosis equivalent and thus compliance may become an issue. It may also be used in cases of recurrent lateral ankle sprain, to ensure that the rearfoot pronates rather than supinates at initial contact.

A flare should also be considered as a feature on a patient's existing footwear that you may want to consider as part of the aetiology of the reported foot or lower limb problem. Some retail footwear may have some flare for cosmetic reasons but this will alter foot movements and subsequent foot function, and may elicit medial foot pain as a result of increased pronation of the foot.

In cases where footwear does have a lateral flare, such as some running footwear, the flare may be constructed of soft material such that it deforms quickly under load. This may negate any effect it might have, and in fact is deliberate so that the stiffer material on the medial side of the heel can have a wedging effect on the heel.

The medial flare will have the opposite biomechanical effect to the lateral, increasing inversion moments at the rearfoot and varus moments at the knee. It will thus increase resistance to pronation and be an alternative or additional means of controlling foot motion.

Heel elongations

An anterior-medial heel extension, or Thomas heel, provides medial arch support complementing orthotic therapy in pronated foot types, painful arthropathy and Charcot deformity. A lateral Thomas heel supports the cuboid region. A medial heel extension can affect plantar pressure by shifting it more laterally than a standard heel and it prolongs the duration of pressure over this area (Figure 7.5).

Rocker soles

Rocker soles are the commonest sole modification and are considered the most effective forefoot offloading method, potentially reducing movement and pain, compensating for loss of motion and reducing forefoot pressure, which is particularly useful in patients with diabetes and a history of ulceration or identified excessive forefoot pressures (Dahmen et al 2001). They have been found to be useful in those with transmetatarsal amputations (Mueller et al 1997). Functioning on a rigid sole, they rock the foot without the foot flexing from heel strike to toe off. The design features a flat or negative heel and midfoot area with a distinct toe spring

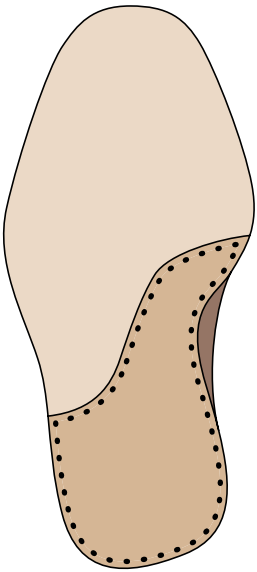

Figure 7.5 Elongated heel

(elevation) at the front of the shoe, distal to the metatarsal heads (Figure 7.3). The principal is that as load is transferred from the heel to the forefoot, the stiffness of the sole prevents the midfoot and toes from flexing. This reduces the transfer of load to the forefoot and maintains loading in the midfoot area (also the heel area in some rocker shoe designs). In the propulsive phase of gait, the shape of the toe spring allows the wearer to 'roll off' more efficiently as the next step is started on the opposite side.

There is a multitude of different designs of rocker sole. They may be curved or angled in profile (angled ones are often called a metatarsal bar) (Figure 7.6) and include toe only, heel to toe, negative heel, severe angle and double rocker. They must be matched with the patient's needs, the condition and the desired effect. The variations are based on the mid-stance section, the apex of the rocker (the pivot point), the profile and the severity of the rocker, which can be between 20 and 30 degrees. Studies support the use of rocker soles but highlight that the practitioner needs to be aware of loading other areas of the foot as this may cause other problems. This is particularly evident in the diabetic neuropathic foot (Cavanagh 2004). Van Schie et al (2000) illustrated the precision required for the placement of the rocker in order to achieve the maximum pressure relief of up to 60 per cent at the metatarsals and 65 per cent at the toes.

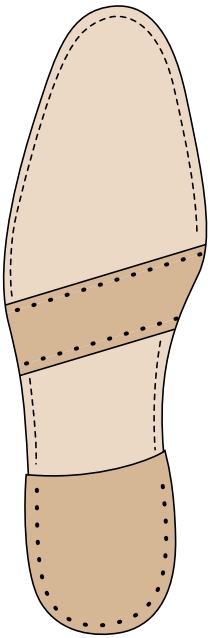

Figure 7.6 Rocker bar

Toe only rockers benefit forefoot pathologies and ulceration by reducing the weight-bearing forces anterior to the metatarsal heads and decreasing the need for toe dorsiflexion. This is useful for hallux rigidus and also for ulcers or callus on the digits.

A heel to toe rocker rocks significantly on both heel strike and toe off but is stable at midstance. This dissipates heel strike calcaneal forces or motion at the ankle, aiding propulsion.

Negative heel rockers are effective in reducing pressure over prominent metatarsal heads and toes, and are of considerable benefit in offloading by shifting pressure to the midfoot. The midfoot loading will be greater in those people with longer stride lengths. Rocker bottom Charcot feet benefit from a double rocker with separate curved rockers at the heel and toe creating two short weight-bearing periods (Janisse and Janisse 2006).

If a slight rocker is required, a style of shoe with an increased toe spring can be useful as can a heel with a cut out (heel striker) at the posterior aspect.

Many variations in the design have been tested: the angle of the toe spring, the site where the angle starts, and combinations of toe spring with negative heel. Some variations have reached consumers directly, such as the Masai Barefoot Technology style footwear that has a distinctive rocker sole.

Forefoot pressure reduction varies according to the insole, precise footwear design features and patient group, but should be in the region of 20 per cent (though some report much higher reductions). Many advocate use of plantar pressure data to inform the design and evaluation of rocker footwear prior to patients using it routinely. This is because subtle changes in the angle and site of the toe spring, in the context of the particular patient's foot anatomy and function, may influence the footwear's effectiveness. Wearers may experience some minor changes in kinematics of the ankle, knee and hip to accommodate the changes in how load is transferred forwards under the foot, but these should not cause concern unless there are pre-existing pathologies at these joints.

As well as use in the foot of a person at risk of ulceration, rocker soles are also used in cases where there is a need to reduce toe flexion (due to pain), or where toe flexion is absent (due to, for example, prior injury or surgical fixation). 'Rocker profile soles are the most commonly used external shoe modification. A recent review of the literature by Hutchins et al (2009) into the biomechanics and clinical efficacy of footwear adapted with rocker profiles found that although they do reduce forefoot plantar pressures, the definitive profile shape has not been defined. Further to this they recommend that further research is warranted into the effects of rocker profiles on individual joints of the foot and the manner in which they effect lower limb muscle activity and gait patterns. A recent and as yet unpublished study by the lead author (Hutchins et al 2009) has investigated the use of rocker profile footwear in cases of intermittent claudication, with reports of improved pain-free walking distances. This seems logical if the profiles alter ankle moments and subsequently alter the activity of calf musculature, but again requires further investigation.'

Sole plates

These are often used in combination with a rocker sole and/or orthoses but can be used on their own to provide a completely rigid shoe. They are usually made from steel. An alternative is to extend the shank of the shoe. The purpose is to prevent normal foot function and relieve pain.

Heel raise or elevation

The purpose of the compensatory raise is in the management of true or apparent shortening of the lower limb. It is achieved by increasing the

sole and heel height of the shoe with the appropriate materials and by the required amount. When requesting an elevation adaptation, the actual height of the raise should be given and should not include the normal sole and heel heights. The external elevation can be either inserted into the existing sole or heel, or added beneath the existing sole/heel (Figure 7.7).

An internal elevation can be no more than 1.5 mm otherwise the foot will slide out of the footwear and there will be problems with forefoot and midfoot fit. The raise will be less than the difference in leg length and it should be tapered towards the toe end to facilitate roll through, and measured at midheel, MTP joints and toe end. Often the difference at these three points is reduced by half, for example 12 mm – 6 mm – 3 mm. A tapered raise takes into account 1.5 cm take off allowance to aid gait through the swing phase.

The outer raise can be made from microcellular rubber, cork or high-density Plastazote. The base of the heel needs to be broad for stability, and the higher the raise the broader the heel needs to be.

Figure 7.7 Outer sole heel raise

When adapting retail footwear for an elevation, it is important that the shoe be a good fit with a secure fastening, and snug around the rearfoot to provide stability. The heel should be low and broad, again for stability. If the required external elevation is over 5 cm, it should be added to a boot rather than a shoe. The boot will provide more stability and the weight of the raise will not pull the boot off the foot, as may happen with a shoe. The type of sole must be suitable for outside adaptation. Some soles cannot be filleted because of their honeycomb construction.

SACHs

Foot function and shock absorption can be improved using a solid ankle cushion heel modification or SACH, in which a medial or lateral portion of the heel unit is replaced by a wedge of less dense material. The rear wedge of the heel then dissipates the shock at heel strike while the denser anterior portion stabilizes or controls midstance. A lateral to medial SACH may reduce hyperpronation in children. Calcaneal pain may be improved with shock reduction as can rigid ankle deformities. A combination of a rocker sole and a SACH can improve gait where there is minimal motion in the joints as a result of joint fusion or arthritis.

Upper adaptations

Tongue pads can provide extra cushioning to the dorsum of the foot, and can be used to decrease the girth of the shoe over the instep.

Clinical decision making for footwear choices

Although the footwear options have been described, clarification is required as to which patients benefit from specialist footwear.

Who should be referred for specialist footwear?

Patients may benefit from specialist footwear if they suffer from:

1. Functional or structural problems associated with systemic diseases, for example a diabetic neuropathic foot, Charcot foot, rheumatoid arthritis foot deformity.
2. Structural problems caused by trauma, fractures and grafts.
3. Structural problems caused by amputations or other surgical procedures.
4. Functional or structural problems of the lower limb which impact on the foot, for example leg length difference due to Paget's disease, or muscle wastage due to stroke.

5. Width, length (heel to ball), depth and lack of symmetry outside the range of available retail footwear.
6. Any foot problem requiring substantial foot orthoses which cannot be accommodated in retail footwear.

Referral for therapeutic footwear is not made on the basis of these considerations alone, however, and further important issues should be considered to increase the likelihood of a successful outcome.

As it is known that there are poor levels of use of specialist therapeutic footwear, there are issues that need discussing with the patient before referral for specialist therapeutic footwear so that they have realistic expectations of the footwear they receive:

- Information about the potential benefits: comfort, fit and improvements in foot, and general function.
- Information about potential constraints such as limited styles and colours, the number of pairs supplied and the poor suitability of the footwear for hot weather.
- The patient should see the footwear catalogues and, if available, a pair of the shoes before being referred.
- Above all, the patient should be allowed to raise any concerns.

Footwear fitting

Length

The overall length of the footwear can be checked by feeling the front of the upper over the toe box. If the toe box is not too hard, the ends of the toes can be located. There should be 1 cm space at the end of the longest toe (and remember, it may be the second or third toe, not the first, that is the longest). If the toes cannot be located through the upper then the foot can be drawn around on a piece of paper and a strip 1 cm in width can be cut from it, from the heel to the tip of the longest toe. This strip is then inserted into the shoe and there should be a gap of 1 cm when the strip is slid forwards to the toe area. At the same time the shape of the toe box can be checked for suitability in relation to the toes.

The correct heel to ball length can be ascertained by checking that the widest part of the foot is in line with the widest part of the shoe.

Width

Terms such as narrow, wide, regular and extra wide may be used by both retail and specialist footwear manufacturers to indicate a size width. These

terms are not standardized and the manufacturers use them at their discretion, therefore it is necessary to know the measurements in relation to the descriptors of the width measurement.

Heel seat

If this is too narrow then the heel will not sit properly on the seat of the shoe and the heel counter may distort. If the dimensions of the foot in this area are large enough to distort the shoe, referral for wider stock footwear may be a good option. If the heel seat is too wide, as may be the case with very narrow feet, the back of the shoe will slip off and there may be side-to-side movement. A supplier of extra narrow retail footwear should be found (for example, James Inglis; see http://www.jamesinglis.com).

Heel counter

The fit of the heel seat and heel counter are essential for the overall fit of the footwear and if these areas do not fit, the whole fit is compromised. If the heel counter is too low or too soft then the foot will feel unstable and this area will distort and wear out quickly. Once the heel counter has collapsed, the upper and the sole unit will rapidly wear out.

If the top-line of the heel counter is too hard, it will dig into the Achilles tendon or the malleoli and may cause blisters.

Instep

There should be one finger width between the facings when the shoes are laced up. If the instep is too loose with the laces fastened, there is too much volume in this area. In this case often the facings overlap when the shoes are fastened. Conversely, if the facings are pushed apart by oedema or bandages, or if the arch of the foot is very high, it may be necessary to refer for specialist therapeutic footwear to accommodate these problems.

Entry to the footwear

If the entry is too wide or deep, the foot will slide forward in the shoe and the heel will slip at the back. This can be compensated for in some instances by putting a liner in the shoe or padding the tongue of the shoe to prevent slippage forward.

Heel height

Wearing a heel rather than a flat sole will tend to shift load from under the heel towards the forefoot, with a clear relationship to increased forefoot pressures. However, these may be of concern only when heel height becomes significant and only when the forefoot area is not appropriately protected.

A small heel may be advantageous because most people have worn a heeled shoe all their lives and removing the heel may increase stress on the Achilles tendon and posterior musculature. Since the effect of a heel is to slightly plantarflex the foot relative to the leg, as the peak of dorsiflexion occurs in late stance, less dorsiflexion will be needed to advance the body's centre of mass over the foot. Reduced dorsiflexion will reduce the stress experienced in the Achilles tendon.

A change in Achilles stress has been linked to altered calf muscle activity and, since gastrocnemius crosses the knee, altered knee and even hip function; however, there is little tangible evidence of effects of small heels influencing joints quite so proximal.

A small heel of approximately 4 cm (depending on shoe size) is therefore beneficial. Additional height should be used only where there is a clear difference in limb length. While much is made of the importance of symmetrical gait and limb length, human anatomy is rarely symmetrical and small (<1 cm) differences may be generally ignored. Measuring for limb differences is very subjective and identifying that one limb is longer than another is probably accurate only if the difference is 5 mm or more. Less than this and soft tissue compression and the position of the patient can quickly provide false positive results. It is often advised that multiple measurements be carried out over a series of visits in order to take into account variations in measurements and the process of measuring.

Controlling foot motion with footwear

As the foot hits the ground it will evert, the medial arch will lower and the midfoot dorsiflex as load is borne under the forefoot. The design, construction and choice of materials will influence the extent to which the shoe resists this movement. This could be an advantageous function, in order to reduce foot pronation for example, which may assist in resolving foot and lower limb symptoms, but it may also cause problems, such as blisters and sites of high pressure. The role of orthoses to control foot motion has already been covered, so here the focus is footwear.

In combination with the heel collar height and throat of the shoe, the contact area between the shoe upper and the dorsum of the foot, the

lacing design and tightness, and the material of the shoe upper will all influence the movement of the foot in the shoe. The uppers and lacing apply a compression force against the dorsum of the foot, in effect holding the foot down against the sole of the shoe. The lateral aspect of the upper will be stretched by pronation of the foot and can thus resist pronation if it is stiff enough and if the lacing creates sufficient compressive forces against the foot. The upper material on the medial side experiences compression, but may resist the foot movement if it is sufficiently stiff, particularly if there is some medial arch support built in. If the shoe is made with too much material on the lateral and medial sides of the foot then it will be ineffective in controlling foot motion inside the shoe. In the area of the medial arch, the width of the sole at the site of the navicular can influence the angle at which the shoe upper contacts the arch of the foot.

The stiffness of the material is a key feature of any ability to resist foot motion. The stiffener used in the heel counter will resist heel eversion if it extends sufficiently on the medial and lateral sides of the heel. The shank between the heel and forefoot will help prevent midfoot motion since this relies on dorsiflexion of the shoe in this midfoot area. It will also help resist frontal plane twisting of the shoe, another component of pronation of the foot. Sole stiffness will also resist the stretching of the sole created by sole dorsiflexion, and thus resist midfoot dorsiflexion.

As well as using wedge material on a foot orthosis to control pronation of the foot, the materials of the sole can also be used to influence foot motion. Wedges can be incorporated into the sole unit themselves, or materials of different stiffness can be used on the medial and lateral sides of the heel. Using a stiffer material on the medial side will help increase inversion moments acting on the heel, and thus help resist eversion of the heel – a component of pronation. The use of mixed materials in the sole unit is one of the key features of running footwear that purports to 'control pronation of the foot'. This footwear often has an insert on the medial side of the shoe that is higher density than the rest of the sole unit.

Footwear suitability assessment tools

In relation to the fit of the footwear, there are assessment tools that help the patient and the practitioner to evaluate fit and suitability. Footwear assessment practices tend to be subjective and to focus on the style of the footwear rather than the suitability of the footwear for the individual patient and their presenting foot problems. Non-specialist footwear assessment relies on length and sometimes width and heel to ball meas-

urement, but generally ignores depth. Patients can usually understand what is meant by width but may not understand the concept of depth unless it is demonstrated by the practitioner. Owing to the differences in the lasts used for different footwear and even differences in international sizing, there is lack of standardization. This makes it difficult for patients to be able to identify for themselves footwear which is suitable for their foot health and their needs in respect of footwear usage. To address this problem a Footwear Suitability Scale was developed (Nancarrow 1999) specifically for patients with diabetes. This has proven to be a useful tool in practice in non-diabetic patients and as an educational tool in ensuring that practitioners are able to identify, rationalize and explain the importance of each part of the shoe when providing advice for the patient (see Table 6.2).

Evaluation of specialist therapeutic footwear

The 'Monitor Orthopaedic Shoes' (MOS) (see Appendix) has been developed and validated by a team in the Netherlands (van Netten et al) based on previous work by Jannink (2005 and 2004). The MOS is a short and easy to complete questionnaire that aims to measure the most relevant aspects of use and usability from a patient's perspective, for all patients to whom this footwear is provided – independent of disorder. MOS is an evaluation instrument that can be used on two levels: first, it can measure expectations (prior to prescription) of, experiences with, and use and usability of footwear; second, the practitioner can use MOS as an evaluation instrument that can help in identifying problems with footwear on an individual level prior to provision or after wear. Insight into the use and usability of footwear on both levels may lead to better identification of problems related to usability, increasing patient satisfaction and rates of use.

During the development of MOS, the emphasis has been placed on the content validity of the evaluation instrument. Good content validity increases motivation and reduces dissatisfaction among users (practitioners) and respondents (patients), and makes it more likely that other stakeholders (such as policymakers and health insurance companies) accept the results.

MOS can be used to gain an insight to patients' opinions on measured aspects of use and usability separately. MOS was specifically designed for first-time users. The difference between first-time and experienced users is essential in the interpretation of outcomes of MOS. First-time users compare their (future) pair of orthopaedic shoes (OS) with their normal shoes, whereas experienced users compare their new pair of OS

with their previous pair(s) and previous normal shoes. This different frame of reference influences expectations and experiences of a user's (future) pair of OS, and thereby the outcomes of MOS. When MOS is administered to a group of patients, therefore, the outcomes of first-time users and experienced users should be separated. Further, keep in mind that some questions might have to be added when MOS is administered to experienced users, for example with regard to the number of pairs that are being, or have been, used.

MOS is the first evaluation instrument that can be used to gain an insight to the most relevant aspects of use and usability of footwear, which can be used for all patients to whom footwear is provided independent of disorder, and which is short and easy to complete (see Appendix).

Summary

In addition to ensuring that the footwear is suitable for purpose, and the design of the footwear is such that no harm is inflicted on the feet, footwear fit is crucial in achieving and maintaining good foot health. This is particularly so for those people who have systemic diseases that affect the feet. The next chapter explores footwear for people with diabetes, rheumatoid arthritis and for those with problems associated with the aging process.

Review questions

Reflection

1. Do I know how to arrange specialist footwear for my patients? Who is my contact in this area?
2. Do I know which patients would benefit from specialist footwear?

Self-assessed questions

1. What are the factors that make a good shoe?
2. Describe the difference between stock and bespoke therapeutic footwear.
3. Which outer sole adaptation is useful if the patient has a fixed excessively pronated foot?
4. How much internal elevation can be achieved in the average shoe?
5. Why is the heel counter important?

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CHAPTER 8

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The relationship between footwear and the vulnerable foot

Introduction

With the growing foot, well fitting, well designed footwear should be seen as an investment for future good foot health and function, and commonly this happens, however, it is not only children who benefit from good footwear. In the adult, inappropriate footwear can impact on mobility, general health, independence and lifestyle; for example, in patients with high-risk foot disease and in the elderly, for whom appropriate footwear should be advised or provided with the aim of preventing limb- and life-threatening morbidity, falls and related problems such as fractures, loss of mobility and loss of independence.

For both the practitioner and the patient, footwear is often considered the most problematic aspect of managing foot pain, deformity and the risk of ulceration, in relation to the footwear style, its acceptability and the fit, with or without foot orthoses. The appropriate fit for patients with diabetes and rheumatoid arthritis (RA), for example, is often difficult to achieve in retail footwear. A study by Chantelau and Gede (2002) found that out of 568 patients, over two-thirds had feet that were considerably

Figure 8.1 An attempt by a patient to make the footwear fit by cutting the uppers

wider than the footwear available from high street retail outlets. Although there is no research to demonstrate the same problem in RA patients, it is perceived that there is the same issue because of the extent of forefoot deformity in this patient group. Often these patients resort to wearing sandals through the whole year or adapting their footwear in a variety of ways such as cutting the uppers to accommodate deformity (Figure 8.1). Appropriate retail or specialist footwear can therefore be of value for a range of patient groups for whom plantar pressure relief, reduced skin abrasion, reduction in foot pain and improved stability would be advantageous.

Footwear and rheumatoid arthritis

In early rheumatoid arthritis, patients often report problems with shoe fit owing to swelling associated with synovitis. Later in the disease process, changes in foot shape often occur including hallux abducto-valgus, clawing of the lesser toes (Michelson et al 1994), narrowing of the heel in relation to the forefoot, prominences such as bursae over the plantar aspect and valgus rearfoot deformity (Woodburn et al 2002). Therefore in both early and established RA, patients often resort to buying footwear a size larger to accommodate these problems. As the foot deformity increases, the patients may need referring for specialist therapeutic footwear (Figure 8.2). The reasons for this referral are foot pain and associated disability, particularly if the patient is experiencing pressure lesions that can occur on the dorsum of the toes (Figure 8.3), on the plantar aspect or around the periphery of the feet. The requirement may be for specialist footwear (Figure 8.4) to reduce the need for foot surgery, but the need also be for substantial foot orthoses, such as total contact foot orthoses (Figure 8.5), or for the footwear to be made of materials that protect the foot from injury or provide a therapeutic effect, such as a lining impregnated with silver, which is known to have a bacteriostatic effect.

The use of therapeutic footwear in patients with RA is supported by some evidence (Fransen and Edmonds 1997) of significant improvements in physical function, walk pain, stair pain and pain-free walk time without an increase in the use of walking aids or arthritis medication compared with those who wore their regular footwear. Further to this study, Williams Rome and Nester (2007a) showed a reduction in pain, increase in activity and improved general foot health.

A systematic review by Farrow et al (2005) concluded that functional custom-designed semi-rigid foot orthoses and extra-depth shoes, especially if combined, are likely to be beneficial; however, Williams and Nester (2006) highlight the complexity of factors which impact on the clinical outcomes from this footwear in respect of personal issues for patients, such as cosmetics, the perceptions of others regarding their footwear and the stigma of foot deformity and disability. This study concluded that improvement in pain, foot health and patient satisfaction with the new design of footwear for patients with RA over the traditional design indicate the importance of patient involvement in the design process and throughout the process of supplying and monitoring the footwear.

Footwear for patients with diabetes

For people with diabetes, appropriate footwear is often used as a protective intervention before major foot pathology develops, in an attempt to

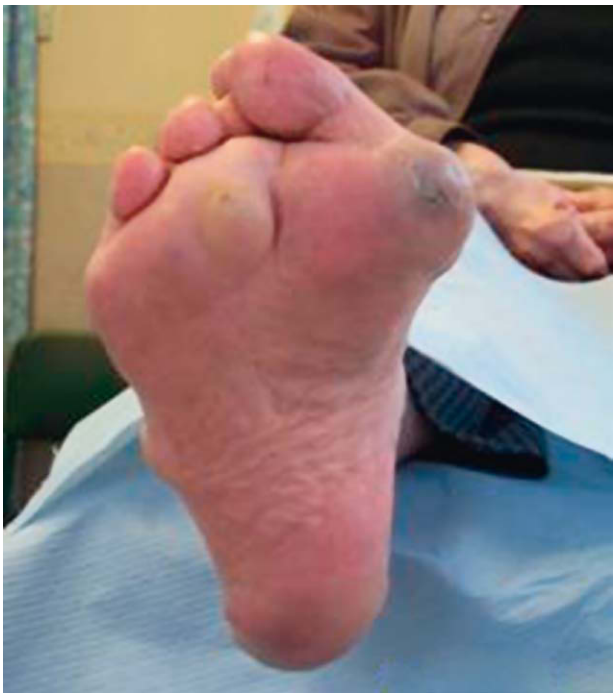

Figure 8.2 Increased RA foot deformity requiring specialist footwear

reduce the forces that cause callus. Callus formation is known to be the precursor to ulceration in this patient group and therefore it is important that the forces that cause this be reduced. These forces can be direct, shear or tensile, or a combination of two or more. All lead to inflammation in the tissues, excess callus formation, tissue damage and ulceration. Examples of the forces include:

- One episode of high pressure causing direct trauma to the tissues, for example standing on a nail.
- Intermittent pressure caused by walking (and increased with mechanical influence from, for example, leg length difference causing increased pressure on the medial aspect of the longer leg if it is pronating as compensation – Figure 8.6).
- Continuous pressure caused by tight footwear; even low forces may prevent circulation of blood to the tissues, causing ischaemic changes.

Figure 8.3 Pressure on the toes of an RA foot

Figure 8.4 Stock footwear for the RA foot

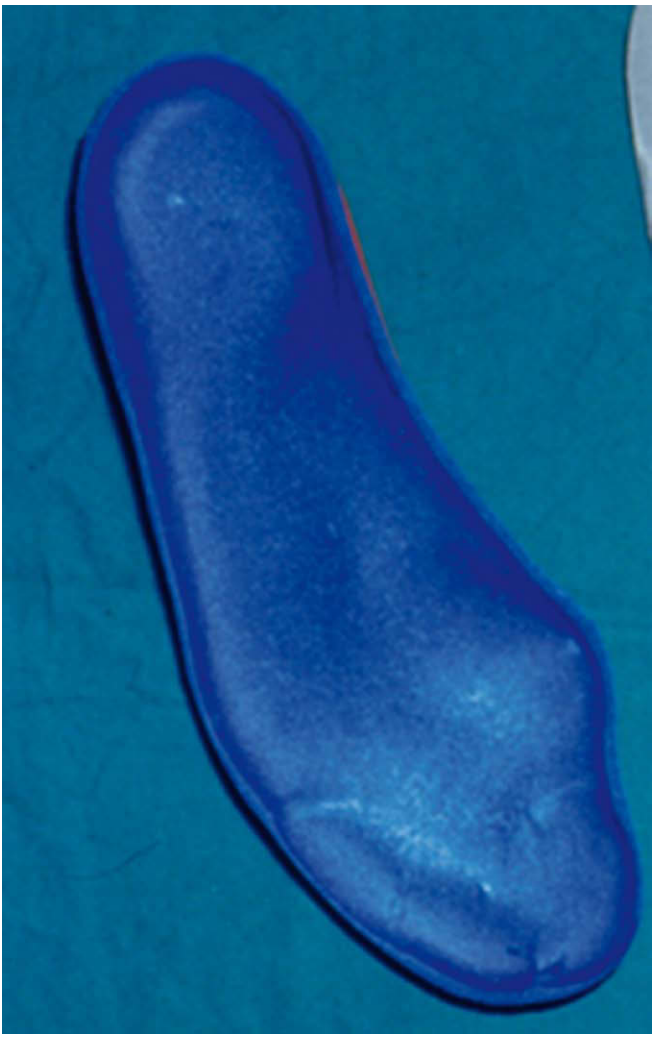

Figure 8.5 Total contact foot orthosis

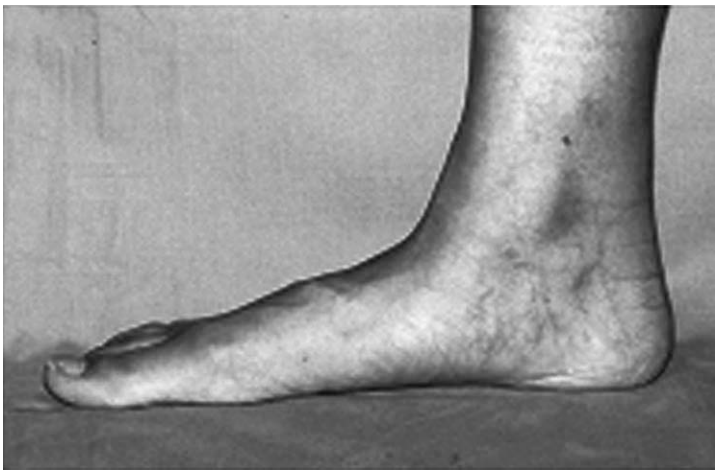

Figure 8.6 Excessive pronation associated with leg length difference resulting in increased pressure on the medial side of the foot

Pressure from tight footwear in patients with neuropathy is a common problem as they tend to chose shoes that are too tight. The reason for this is that they are trying to achieve the sensation of feeling the shoes on the feet and increased proprioception. This leads to continuous pressure at the margins and toes, preventing normal toe function and increasing pressure on the metatarsal heads. Additional forces across the metatarsal heads are a result of the development of the high medial longitudinal arch together with displacement or atrophy of the plantar metatarsal fat pad, which result in an inability to absorb the increasing forces. Stiffening of local soft tissues through glycosylation also adds to the loss of resilience. There may be also areas of localized high pressure as a result of limited joint mobility, also through glycosylation, and the shoes may become tight because of oedema. This is particularly a problem in the neuroischaemic foot because patients with peripheral vascular disease often have renal and cardiac problems which lead to peripheral oedema. There may also be problems with swelling when the foot is ulcerated and/or infected, or if the patient develops acute Charcot neuroarthropathy.

There are studies to support the belief that inappropriate footwear, purchased by patients in retail outlets, can cause ulceration. Apelqvist et al (1990) identified footwear as the precipitating cause in the majority

of toe ulcers and a significant number of lesions elsewhere in the foot, and McGill et al (2005) found that footwear trauma was the precipitating factor in 54 per cent of ulcers in their study of 250 patients with diabetic neuropathy. Therapeutic footwear is therefore often recommended by clinicians in an attempt to minimize the trauma often associated with patients' own retail footwear.

When ulceration does occur, it is necessary to offload the foot completely using total contact plaster of Paris casts or removable devices such as the cam walker. Once the foot is ulcer free, management may require a combination of appropriate foot orthoses and footwear.

***Author** Note*

Offloading one area may overload another, so care must be taken as the shift in forces can cause ulceration elsewhere or even trigger Charcot neuroarthropathy.

Not all patients with diabetes need therapeutic footwear, but the vast majority will benefit from some type of insole or orthosis to improve function, redistribute foot pressures and/or provide cushioning. Extra-depth stock therapeutic footwear may be a preferred option because it can accommodate the foot and the chosen orthosis. This footwear is provided in a range of sizes, fittings and combination of fittings, for example wide and deep. The decision to opt for bespoke therapeutic footwear is taken when the feet do not fit into the range of sizes and fittings provided by stock footwear manufacturers. An attempt at an algorithm for clinical decision making for footwear and foot orthoses for those with diabetes is detailed in Table 8.1. This has been developed from the best available evidence and reflects what is considered to be best practice.

The effect has been studied of therapeutic footwear as a primary intervention in the prevention of re-ulceration in those considered at high risk of ulceration (Cavanagh 2004, Busch and Chantelau 2003). Those patients who wore their shoes daily (regular wearers) were significantly less likely to have re-ulceration compared with patients who wore them infrequently. The influence of wear on the effectiveness of footwear properties has been identified, and it is recommended that patients have two pairs at any given time. Therapeutic footwear in isolation is considered to be less effective than when it is provided with a package of care including foot care and foot health education (Dargis et al 1999, Uccioli et al 1995, Edmonds et al 1986).

There are various objectives of footwear interventions in the vulnerable foot, and any combination of these may be indicated in any particular patient:

1. Relief of excessive plantar pressure: the typical daily activities of life produce pressure on the foot which, in insensate feet, can lead to callus formation and the development of ulceration, particularly over areas of greatest pressure such as the metatarsal heads. Orthoses can help to reduce these pressures by redistributing them more evenly over the plantar aspect. However, many retail shoes do not have sufficient depth to accommodate the foot and the foot orthoses, and specialist therapeutic footwear may have to be provided.
2. Reduction of shock: even moderate pressure can cause problems with callus and ulcer formation if it is repetitive. Cushioning materials in both the foot orthoses and the outer sole of the footwear contribute to the reduction of these forces.
3. Reduction of shear: the reduction of the horizontal and vertical movements of the foot within the footwear is important in reducing the damaging effects of skin shear and friction which can cause blisters, and contribute to callus formation and ultimately ulceration.

Table 8.1 An algorithm for footwear and foot orthoses options for people with diabetes

Risk category	Definition	Recommended footwear
0	Protective sensation intact	Well fitted, appropriately designed retail footwear
1	Neuropathy/no deformity	Shock-attenuating insoles and extra-depth shoes (retail or stock therapeutic footwear)
2	Neuropathy with mild deformity	Extra-depth stock therapeutic footwear with accommodative or moulded foot orthoses
3	Neuropathy with significant deformity and history of pressure induced ulcer	Modular or bespoke footwear with accommodative or moulded foot orthoses and rocker outer sole
4	Neuropathy with severe deformity and history of pressure-induced ulcer and/or amputation of toe(s)	Modular or bespoke footwear with accommodative or moulded foot orthoses and rocker outer sole
5	Neuropathy with complex deformity, chronic ulceration, partial foot amputation or unilateral lower limb amputation	Bespoke shoes or boots with accommodative or moulded foot orthoses or ankle-foot orthoses and a rocker outer sole

The foot therefore needs to be securely fastened in the shoe to prevent slippage, twisting and the foot shunting forwards in the shoe during the gait cycle.

4. Accommodation of deformity: motor neuropathy and limited joint mobility from tissue glycosylation lead to digital and metatarsal deformities. Gross deformity from Charcot neuroarthropathy and amputations also needs to be accommodated.
5. Stabilization and support of deformities: some deformities need to be stabilized to relieve pain and prevent further destruction, for example, a heel counter can be reinforced or extended medially and laterally to aid support along with orthotic therapy and outer sole adaptations.

Footwear for the older person

Around one in three older people fall at least once each year (Tinetti et al 1988). Hip fractures are one of the most serious consequences of falls. By the age of 90, up to 32 per cent of women and 17 per cent of men have suffered a hip fracture (Gallagher et al 1980), and it has been estimated that by the year 2050 there will be up to 2.3 million annual hip fractures globally (Gullberg et al 1997). Sherrington and Menz (2003) identified that risk factors for hip fracture include decreased bone mineral density, increased age, previous falls and fractures, poor health status, inactivity, impaired walking and balance abilities, poor vision, psychoactive prescribed drug use and a high caffeine intake. Further to these factors, the fear of falling can itself curtail mobility and quality of life. Prevention of falls is thus an important clinical and public health problem for older adults.

A potential risk factor for falls and fractures is footwear, as many older people wear footwear with features that are potentially hazardous or at least offer suboptimal support. Finlay (1986) assessed the footwear of 274 patients attending a geriatric hospital and reported that only half were wearing 'adequate' footwear. The most commonly observed inappropriate features were excessively flexible heel counters, high heels and narrow heels. In addition, 50 per cent of shoes worn had heel slippage, and unsatisfactory heel counters were evident in 63 per cent of all slippers.

A number of studies have investigated the influence of various shoe features on balance ability in older people. It is known that many older people wear footwear with features that are potentially hazardous or unsupportive. An elevated heel of only 4.5 cm in height significantly impairs

Figure 8.7 Excessive heel wear and instability

balance in older people (Menant et al 2008). Figure 8.7 shows an example of heel wear caused by an unstable heel, further leading to instability.

Heel height and width may affect a shoe's tendency to tip sideways on an uneven surface, as well as affecting gait and posture. Soft-soled shoes impair beam-walking performance (Robbins et al 1992), and high heel counters have been shown to improve balance compared with standard, low-cut footwear (Lord et al 1999). Inadequate slip resistance of the outersole of the shoe is also thought to increase the risk of slipping accidents (Menz et al 2001) but no studies have directly evaluated this in elderly subjects. Based on this information, the 'ideal' safe shoe for older people is thought to consist of a low, sturdy heel, high heel counter, a thin, firm midsole and a textured sole.

The available evidence seems to indicate that inappropriate footwear may impair balance in older people, possibly leading to an increased risk of falling. Sherrington and Menz (2003) concluded that many older people who have had a fall-related hip fracture were wearing potentially hazardous footwear when they fell. The wearing of slippers or shoes without fixation may be associated with increased risk of tripping and it is also known that the risk of falls increases in barefoot elderly.

If we are to recommend new shoes to our patients, we must ensure that they have access to facilities where their feet can be measured and

shoes can be fitted correctly; however, White and Mulley (1989) found that 25 per cent of community-dwelling older people were unable to get to a shoe shop. These authors suggested the alternatives of mobile shoe shops, where trained staff can go out into people's homes to fit shoes, or mail order, which may be more convenient.

Laboratory-based studies have examined gait, balance and tactile perception in relation to features of shoe design, using volunteers under controlled conditions. Interestingly, relatively thick, soft midsoles have been found to interfere with position sense and contribute to instability, as assessed by falls off a balance beam, raising questions about the safety of athletic shoes. High-heeled shoes have been found in a gait laboratory to lead to lateral instability and reduce stride length. These findings have been demonstrated in the laboratory setting and it may be that the risk of falls (attributed to footwear as the primary cause) increases in the normal environment.

Summary

The importance of good footwear, whether it be high-street retail footwear or specialist therapeutic footwear, should be part of every consultation with a patient presenting with foot pathology. In respect of the elderly and the at risk person with, for example, diabetes or RA, footwear considerations are vital in the maintenance of good foot health, reducing symptoms, improving mobility and independence, and preventing limb-threatening ulceration. It is clear from the evidence available that therapeutic footwear is beneficial to people with diabetes (in preventing re-ulceration) and to people with RA. However, to achieve the known benefits, it is crucial that this footwear be worn sufficiently to maximize the potential for all these benefits. Unfortunately, some people find that this footwear is unsuitable because of its appearance. This problem can be overcome with better footwear designs and also a more patient-focused approach to the consultation (Williams Nester and Ravey 2007b) so the next chapter aims to provide the practitioner with the knowledge and understanding of what can be done to improve patient understanding and engagement with appropriate footwear-wearing habits.

Review questions

Reflection

1. How would I describe the benefits of therapeutic footwear to a patient with RA?

2. Do I know the evidence to support the features of footwear that are suitable for an older person?

Self-assessed questions

1. What are the main reasons for referring someone with diabetic neuropathy for specialist therapeutic footwear?
2. How would you assess the footwear fit for someone with diabetic neuropathy?
3. Given the benefits of therapeutic footwear, what would you advise a patient with diabetes to wear around the home?
4. What are the important benefits of specialist therapeutic footwear generally?
5. What are the key features of safe footwear for the older person?
6. What is the effect of wearing thick, soft-soled shoes in the elderly person?

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CHAPTER 9

Managing patient engagement in orthoses and footwear as a foot health intervention

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Introduction

It is important for the practitioner to understand retail trends, and sources of suitable footwear. Having leaflets of different footwear brands may be useful in educating and informing patients about sources of good footwear but the most important factor in getting patients to change their footwear-wearing behaviour is for the practitioner to understand that it may take some time. It is known that just because someone has knowledge, this does not necessarily influence their behaviour. Having the knowledge may be the start of a process for patients to think about change, action change and then maintain the change (Prochaska and DiClemente 1984, 1982).

In situations where patients' shoes contribute to symptoms but there is no apparent conscious acceptance of this, then the practitioner may have to accept that this is the patients' personal decision. Under these circumstances, negotiated care or compromise is required.

Managing use issues with specialist footwear

There have been reports that specialist footwear services are failing to meet the needs of the individual patient (Bowker et al 1992, Disabled Living Foundation 1991) despite evidence to support the use of specialist footwear to achieve good clinical outcomes. To achieve good clinical outcomes means that patients have to wear their footwear for sufficient time to maximize their potential for foot health improvement or maintenance. That many patients choose not to wear this type of footwear may be indicative of the lack of patient involvement in this therapeutic approach.

It has been recommended and observed that patients engage more with this footwear if it is supplied through a multidisciplinary clinic (Williams and Meacher 2001) or through the service that provides foot care (Baker and Leatherdale 1999). A study by the authors (Williams and Nester 2006) demonstrated that patient involvement from the design process through to patient choice may be the key to getting patients to engage with this type of footwear. However, the main factor may be the consultation (Williams et al 2008). It is essential, therefore, that the practitioner involved in providing footwear advice or assessing and supplying specialist therapeutic footwear should adopt a patient-focused approach that includes the patient in the decision making process.

Patient education and behaviour change

Footwear can be perceived by individuals in a variety of ways, depending on what the shoes required offer. Footwear can provide a specific function, for example toe protection in safety shoes, but is for many people inextricably linked to body image. In this respect, fashion trends can dictate the style and type of footwear worn by individuals. The achievement of a good clinical outcome for the patient relies on managing expectations, and practitioners must recognize that patients may have different aims to theirs. For example, the clinician's aim may be to achieve optimum fit but the patient's objective may be comfort and/or style.

Practitioners need to understand that footwear does not just provide protection for the foot or accommodate the orthoses that we might prescribe; it is part of people's body image and important in respect of how we feel about ourselves. As clinicians, we have to respect people's choice to either engage in our advice or not. Rather than telling patients that their footwear choices are bad, we should provide positive support for the small changes that patients may achieve and continue to promote the benefits of suitable footwear. It is only then that our patients may feel that we are focused on them rather than on just their problems. Focusing on

the person is the key to improving foot health through our intervention of foot orthoses and appropriate footwear.

It is difficult for practitioners to recommend styles as there are constant changes in fashion. It is better to recommend certain aspects of footwear which are important features with regards to fit (see Table 6.2, p. 100). These features may vary slightly according to the specific foot problems; for example, a patient with an ankle equinus may benefit from wearing a sturdy but higher heel than those generally recommended without developing forefoot pain and deformity.

Giving footwear advice is particularly seen as the podiatrist's role although any healthcare practitioner dealing with foot pathology should be able to do this, However, doctors have been reported as identifying that they lack both the time and the specialist knowledge to give this advice (Williams and Meacher 2001).

Some patients think that good footwear has to be expensive and conversely that expensive footwear is considered good. This does not have to be the case, however, and often with good knowledge of local retail outlets, footwear styles available and prices, patients can be guided to the shops that supply appropriate footwear that the patient can afford.

Resources for the practitioner and patient

The British Footwear Association (http://www.britfoot.com) provides information about footwear manufacturers and retailers, and also where to find footwear for feet that are outside of the normal ranges of retail footwear, such as extra large, extra slim, or odd sizes for those with different-sized feet. It is important that the practitioner be able to show patients the type and design of footwear that would be suitable for their foot health. Many footwear manufacturers will provide samples of their footwear to be used as visual aids in the provision of footwear advice and also footwear leaflets for the patient to take away with them.

In order to ensure that the right size and fit of footwear is purchased, the practitioner can measure the feet using a size stick or better still the Brannock device (see Figure 6.7, p. 97) but remember that this is only a guide as the footwear dimensions will vary from style to style and manufacturer to manufacturer.

The Disabled Living Foundation (http://www.dlf.org.uk) provides fact sheets for 'Finding Suitable Footwear'. These fact sheets cover information on footwear for problem feet and can be viewed on the website.

The Society of Shoe Fitters (http://www.shoefitters-uk.org) provides a guide to shoe buying and foot care and SATRA (http://www.satra.co.uk)

provides information on materials and testing of new products used in the manufacture of footwear.

For general advice on footwear for arthritis sufferers, the Arthritis Research Campaign (http://www.arc.org.uk) provides a patient leaflet 'Feet, Footwear and Arthritis' (available free; contains an excellent section on suitable footwear for arthritis sufferers).

The Raynaud's and Scleroderma Association (http://www.raynauds.org.uk) provides information on keeping feet warm and specifically what types of footwear can be useful.

Finally, The Society of Chiropodists and Podiatrists (http://www.feetforlife.org) provides information on foot problems and footwear.

General footwear advice

If patients do not have major structural problems with their feet, then the majority will be able to purchase suitable footwear from retail outlets. There is some general advice that can be given to patients whatever their specific footwear needs.

They should be advised to shop at stores that provide service to their customers and have knowledgeable salespeople. Getting properly fitted footwear takes more than picking a shoe off the shelf and having the sales associate ring up your sale. Their feet should be measured, particularly if they have become wider over the years, or have changed shape because of arthritis. Feet may change shape when standing, so it may be preferable to have them measured while standing. If their feet tend to swell, then it is better to shop for shoes later in the afternoon when they are at their largest.

Size varies between shoe brands and style. Judge a shoe by how it feels on the foot and not just by the size marked on the shoe. Ask the patient to think about how the shoe fits around the toes, under the soles, and at the back of the heels.

Many people have one foot bigger than the other, therefore it is preferable to buy shoes to fit the larger foot (an insole can be used in the other shoe). There should be at least 1 cm ($\frac{3}{8}$ in) of room at the front of the longest toe.

Shoes should be tried on with the type of socks or other hosiery normally worn and with any insoles or orthoses. Some insoles may need extra depth, especially in the toe area. The right shoes will be comfortable when you first try them on. Buying shoes to 'break in' later is not a good idea. Ideally, the sole should be able to flex along an imaginary line drawn from the base of the big toe to the base of the little toe.

Leather uppers are usually the most comfortable, and check that they have leather inners (the inner lining). These are more breathable than inners made of synthetic materials and will help avoid dampness and fungal infections.

If the patient is worried about the appearance of their feet, dark colours and a suede finish will help to disguise the problem.

Advise the patient to take time to fully lace and tie the shoes properly and walk around in them before deciding if they are comfortable or not.

Many people prefer to wear slippers in the house rather than shoes, but slippers are not a good idea for those who have to wear special insoles. Slippers also sometimes cause falls in the elderly. The uppers of slippers are often soft and so are comfortable for hammer toes and prominent joints, but the soles can lack adequate cushioning. Like outdoor shoes, slippers should fit properly and should not be too loose. Backless slippers and slippers with a high heel should be avoided. The features of the ideal slipper are generally the same as those of the ideal shoe.

If the patient needs to wear safety boots for work, they should purchase them from a supplier displaying the British Kitemark sign. If existing safety footwear is uncomfortable (maybe the soles are too hard or the toes not roomy enough), patients may need to talk to their employer about getting alternative shoes. Safety versions of extra-depth and cushioned shoes are available.

If the patient has problems with circulation or cold feet, many slippers, shoes and boots are available with linings such as sheepskin or synthetic fur to help keep the feet warm. Wearing thicker socks or two pairs (as long as they are not too tight) not only helps to keep the feet warm but also provides extra cushioning under the soles of the feet. Keeping the feet warm will also be easier if the rest of the body is kept warm.

Summary

Providing patients with footwear advice is often both time consuming and a challenge in respect of changing footwear habits. Having knowledge of footwear construction, fitting and its effect on gait and foot function is crucial for any practitioner involved in the management of the foot. This knowledge is the basis on which we can provide information and advice to our patients. As clinicians, we have to respect people's choice to either engage in our advice or not as footwear plays an important role in our self-perception and perception of how others see us. Focusing on the person and their needs is the key to improving foot health through our intervention of foot orthoses and appropriate footwear.

Review questions

Reflection

1. How am I including footwear as part of foot health promotion?
2. What is my strategy for changing my patient's footwear style and type?

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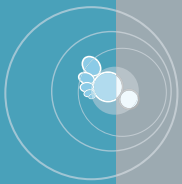


Glossary

Abducted/abduction: joint movement away from the midline of the body along the transverse (horizontal) plane.

Adducted/adduction: joint movement towards the midline of the body along the transverse (horizontal) plane.

Anterior: located in front of a part or towards the front of a structure.

Biomechanics: the study and application of mechanical laws to living structures, especially to the musculoskeletal system and locomotion. Addresses mechanical laws governing structure, function and position of the human body.

CADCAM: computer-aided design, computer-aided manufacture.

Cavoid foot: See **Pes cavus**.

Distal: away from a point of reference or attachment, usually the trunk of the body, relative to other parts of the body. Distal interphalangeal joints are those furthest from the foot.

Dorsiflexed/dorsiflexion: a 'toe/foot up' motion of the foot at the ankle which brings the dorsum of the foot closer to the anterior tibia. Digital dorsiflexion involves moving the toes upwards towards the dorsum of the foot.

Everted/eversion: movement in the frontal plane in which the plantar aspect of the foot is tilted away from the midline of the body.

Flex line: the part of the orthosis or shoe that corresponds to the flexion line of the MTP joints.

Frontal plane: any of the vertical planes passing through the body perpendicular to the sagittal plane; the plane parallel to the long axis of the body and at right angles to the median sagittal plane, dividing the body into front and back portions.

Hallux limitus: evolving osteoarthritis at the first MTP joint which results in progressive limitation of motion at the first MTP joint. Eventually may proceed to a hallux rigidus.

Hallux rigidus: severe limitation of motion at the first MTP joint. The end result of the osteoarthritis that reduces first MTP joint motion to produce hallux limitus.

Hallux valgus: complex deformity of the first MTP joint involving deviation of the great toe toward the lesser toes. Predominantly a transverse plane deformity, but the hallux may also rotate in the frontal plane.

Heel pitch: viewing the shoe from the side, this is the angle created by the heel height relative to the front part of the sole. The higher the heel, the greater the heel pitch.

Hypermobility: generally, refers to increased flexibility of the joints, allowing them to bend or move beyond their normal range of motion, which may be local or generalized; in relation to the foot, can also refer to functional hypermobility, which describes a lack of functional stabilization of an anatomical unit. For example, the pronated foot where the ability of fibularis longus to stabilize the first metatarsal is compromised. This can result in first MTP joint deformity or pathology.

Inverted/inversion: movement in the frontal plane, so the plantar surface of the foot moves towards the midline of the body and away from the transverse plane.

Lateral: denoting a position further from the median plane or midline of the body or a structure.

Medial: denoting a position toward the median plane or midline of the body or a structure.

MTP: metatarso-phalangeal.

Ontogeny: the complete developmental history of an individual organism.

Orthosis (plural: orthoses): a support, brace or splint used to support, align, prevent or correct the function of movable parts of the body. Shoe inserts are orthoses that are intended to correct an abnormal or irregular walking pattern, by altering the angle at which the foot strikes, and interacts with, a walking or running surface.

Orthotic: serving to protect, or to restore or improve function; pertaining to the use or application of an orthosis (an orthotic device, an orthotic service).

Osteopenia: reduction in bone mass, usually caused by a lowered rate of formation of new bone that is insufficient to keep up with the rate of bone destruction.

Pes cavus/cavoid foot: a high-arched foot with an inverted calcaneus. Associated with lateral weightbearing, lateral instability and lateral ankle sprains.

Pes planus/pes planovalgus: an elongated foot with an everted calcaneus and flattened arch.

Plantarflexed/plantarflexion: a 'toe-down' motion of the foot at the ankle which moves the dorsum of the foot further away from the anterior aspect of the tibia. Digital plantarflexion involves moving the toes downwards away from the dorsum of the foot.

Plantigrade: walking on the sole of the foot with the heel touching the ground. Plantigrade function is compromised, for example, in cerebral palsy if there is an ankle equinus which restricts the heel from contacting the ground.

Posterior: located behind a part or towards the rear of a structure.

Pronation/pronated: a combination of dorsiflexion, eversion and abduction movements taking place in the tarsal and metatarsal joints which results in lowering of the medial margin of the foot and hence of the longitudinal arch.

Proximal: nearer to a point of reference or attachment, usually the trunk of the body, than other parts of the body. Proximal interphalangeal joints are those closest to the foot.

Sagittal plane: the longitudinal plane that divides the body into right and left sections.

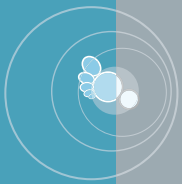
Supination/supinated: a combination of plantarflexion, inversion and adduction taking place in the tarsal and metatarsal joints which results in raising of the medial margin of the foot and hence of the longitudinal arch.

Toe spring: the front part of the shoe sole. The height can range from being completely flat on the floor, i.e. no toe spring, to being elevated enough to create a rocker sole, and is dependent on shoe design and intended function.

Transverse plane: the plane passing through the body from side to side, at right angles to the median plane, dividing the body into top and bottom or superior and inferior parts.

Valgus: a frontal plane position in which the foot or part of a limb is turned outwards away from the midline.

Varus: a frontal plane position in which the foot or part of a limb is turned inwards toward the midline.



Appendix

We would like to encourage readers who are working in the area of specialist therapeutic footwear to use the MOS – it is an ideal tool to evaluate whether footwear is meeting patient expectations Further information about the development of the MOS and data on its reproducibility can be found in the Journal of Rehabilitation. (full reference – van Netten, Jaap J, Hijmans, Juha M, Jannink, Michiel J.A, Geertzen, Jan H.B, and Postema, Klaas Development and Reproducibility of a Short Questionnaire to Measure Use and Usability of Custom-Made Orthopaedic Shoes Journal of Rehabilitation Medicine, 2009, 41:913-918) Please refer to this article in future research. Interested therapists can obtain an electronic copy of the MOS, together with a description of the scoring system, by contacting Dr Anita Williams HYPERLINK "mailto:a.e.williams1@salford.ac.uk" a.e.williams1@salford.ac.uk at the University of Salford.

Furthermore, the authors of this book would like to invite readers into a collaboration whereby collection and reporting of MOS data (anonymised copies) can be co-ordinated nationally/internationally. Contact Dr Anita Williams for further information HYPERLINK "mailto:a.e.williams1@salford.ac.uk" a.e.williams1@salford.ac.uk.

Monitor Orthopaedic Shoes 1

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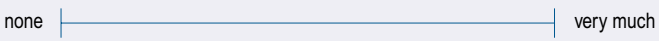
Roessingh Research and Development, Enschede

Instructions: This questionnaire consists of different types of questions. Some examples are given here to demonstrate how to complete your answers. **Read these instructions carefully before you begin.**

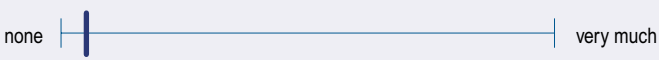
1. All questions concern your situation at this moment.
2. Questions with a **straight line** (an example is given below).
   On the line under the question, you can see at the far left 'none', and at the far right 'very much'.

Example question:

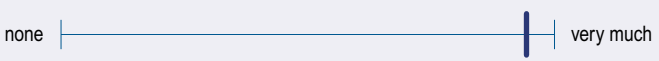
Indicate how much pain you have when shopping.



Draw a vertical mark to indicate how much pain you have during shopping. You can place the mark anywhere on the line.
If you have only a little amount of pain during shopping, you draw the mark more to the left.



If you have more pain during shopping, you draw the mark more to the right.



3. Multiple choice questions, for example:

- ☐ answer A
- ☐ answer B
- ☐ answer C

Here, you have to draw a cross indicating the answer that is most applicable to you.

4. Questions with dots: ……
On these dots you can write your answer, if applicable for you.

Personal information

Are you happy to be involved in this research by completing this questionnaire?

- ☐ yes
- ☐ no

Date: _____
Name (initials + surname): _____
Address: _____
Postal code: _____ Place of residence: _____
Telephone: _____ Date of birth: _____

Gender: ☐ male ☐ female

1. What is your current **walking capacity**? Choose the most appropriate answer.
   - ☐ I can walk inside my house (0–10 metres)
   - ☐ I can walk to the neighbour's house (10–50 metres)
   - ☐ I can walk to the corner of the street (50–200 metres)
   - ☐ I can walk to shops etc. in the neighbourhood (200 metres–1 kilometre)
   - ☐ I can walk a fair distance without rest (more than 1 kilometre)

2. Which of the following **disorders** do you have? (multiple answers are possible)
   - ☐ diabetes
   - ☐ rheumatoid arthritis
   - ☐ foot disorder (including flat foot, claw toes, hammer toes, bunions)
   - ☐ muscle disease
   - ☐ other, please specify: .....

3. Which **specialist** prescribed your orthopaedic shoes?
   - ☐ rehabilitation doctor
   - ☐ orthopaedic surgeon
   - ☐ rheumatologist
   - ☐ other, please specify: .....

4. What is the **most important** reason for receiving orthopaedic shoes? Choose the most appropriate answer.
   - ☐ pain in feet or ankles
   - ☐ wounds/ulcers on the feet
   - ☐ foot disorder
   - ☐ difference in leg length
   - ☐ other, please specify: .....

Current situation

5. Indicate the amount of **pain** you feel in the **skin** of your feet and/or ankles during activities like standing and/or walking.

   none |——————————————| very much

6. Indicate the amount of **pain** you feel in the **muscles and joints** of your feet and/or ankles during activities like standing and/or walking.

   None |——————————————| very much

7. In the following pictures, indicate the location of your **pain** with a cross.

Right

Left

8. Indicate the amount of trouble you have with **spraining** of your ankles.

none ——— very much

9. Do you have any **wounds/ulcers** on your feet and/or ankles?

☐ yes

☐ no (if you answer no, continue with question 11)

10. In the following pictures, indicate the location of your **wounds/ulcers** with a cross.

Right

Left

Expectations of your orthopaedic shoes

11. With your orthopaedic shoes, do you expect to have **less or more pain** in the **skin** of your feet and/or ankles, during activities like standing and/or walking? Indicate the amount of change in pain you expect.

much less ——— much more

☐ not applicable

12. With your orthopaedic shoes, do you expect to have **less or more pain** to the **muscles and joints** of your feet and/or ankles, during activities like standing and/or walking? Indicate the amount of change in pain you expect.

much less ——— much more

☐ not applicable

13. With your orthopaedic shoes, do you expect to have **less or more trouble with spraining** of your ankles? Indicate the amount of change in trouble with spraining you expect.

much less ——— much more

☐ not applicable

14. With your orthopaedic shoes, do you expect that the wounds on your feet and/or ankles will heal?
    - ☐ yes
    - ☐ no
    - ☐ this is for me not applicable

Discussion of your expectations with the doctor

15. Indicate how well the **doctor** listened to you.

    very bad ——————————— very good

16. Did the **doctor** discuss what you can and cannot expect from your orthopaedic shoes?
    - ☐ yes (if yes, continue with question 17)
    - ☐ no (if no, continue with question 18)
    - ☐ I cannot remember (if you cannot remember, continue with question 18)

17. Did you adjust your expectations following discussions with **the doctor**?
    - ☐ yes, I now expect more of my orthopaedic shoes
    - ☐ yes, I now expect less from my orthopaedic shoes
    - ☐ no, I still expect the same
    - ☐ I did not have any expectations

Discussion of your expectations with the shoe technician/orthotist

18. Indicate how well the **shoe technician/orthotist** listened to you.

    very bad ——————————— very well

19. Did the **shoe technician/orthotist** discuss what you can and cannot expect from your orthopaedic shoes?
    - ☐ yes (if yes, continue with question 20)
    - ☐ no (if no, continue with question 21)
    - ☐ I cannot remember (if you cannot remember, continue with question 21)

20. Did you adjust your expectations following discussions with **the shoe technician/orthotist?**
    - ☐ yes, I now expect more of my orthopaedic shoes
    - ☐ yes, I now expect less from my orthopaedic shoes

☐ I did not have any expectations

Expectations with regard to the cosmetic appearance of your orthopaedic shoes

21. Indicate how **ugly or attractive** you **expect** that your orthopaedic shoes will be.

very ugly ——— very attractive

22. What do you expect that others will think of the cosmetics of your orthopaedic shoes?
- ☐ very ugly
- ☐ ugly
- ☐ neutral
- ☐ attractive
- ☐ very attractive
- ☐ I do not know what others will think of the cosmetic appearance of my shoes

23. Did you have any input/choice over the cosmetic appearance of your orthopaedic shoes?
- ☐ yes
- ☐ no

Use of your orthopaedic shoes

24. Indicate how poor or well you expect that your shoes will **fit.**

very poor ——— very well

25. **How much** do you expect to be able to **walk** with your orthopaedic shoes? (Choose the most appropriate answer) I expect that I will be able to…
- ☐ ... walk inside my house (0–10 metres)
- ☐ ... walk to the neighbour's house (10–50 metres)
- ☐ ... walk to the corner of the street (50–200 metres)
- ☐ ... walk to shops etc. in the neighbourhood (200 metres–1 kilometre)
- ☐ ... walk a fair distance without rest (more than 1 kilometre)

26. Is that less or more than you are able to walk now?
- ☐ less than I can walk now
- ☐ as much as I can walk now
- ☐ more than I can walk now

27. With your orthopaedic shoes do you **expect** to be able to do the following activities **less or more?** If you do not expect any change, choose no change.

- walking inside the house: ☐less ☐more ☐no change
- walking around the garden: ☐less ☐more ☐no change
- housekeeping jobs: ☐less ☐more ☐no change
- shopping for groceries: ☐less ☐more ☐no change
- performing work duties: ☐less ☐more ☐no change
- participating in hobbies: ☐less ☐more ☐no change
- going shopping in town: ☐less ☐more ☐no change
- going for a walk: ☐less ☐more ☐no change
- participating in sport: ☐less ☐more ☐no change

Further questions

28. What do you think is more important: that your orthopaedic shoes look good or that your orthopaedic shoes solve your foot problems?

that they look good ——— that they solve my foot problems

more important ← equally → more important

29. What will be the advantages of your orthopaedic shoes?

.....

30. What will be the **disadvantages** of your orthopaedic shoes?

.....

31. Indicate if you expect that the **advantages** will **outweigh** the **disadvantages**.

definetely not ——— certainly yes

32. Are there any other expectations and/or important matters that have not been considered?

.....

33. Do you have any final remarks?

.....

34. How long did it take you to complete this questionnaire?..... minutes

END **Thank you for completing this questionnaire**

Monitor Orthopaedic Shoes II

Authors note – this section of MOS II contains the same instructions as MOS I –for brevity this information has not been repeated here

35. What is your current **walking capacity?** Choose the most appropriate answer.

☐ I can walk inside my house (0–10 metres)

- ☐ I can walk to the neighbour's house (10–50 metres)
- ☐ I can walk to the corner of the street (50–200 metres)
- ☐ I can walk to shops etc. in the neighbourhood (200 metres–1 kilometre)
- ☐ I can walk a fair distance without rest (more than 1 kilometre)

36. **Compared** with the period before you received your orthopaedic shoes, your **walking capacity** …

- ☐ … is improved, because of the orthopaedic shoes
- ☐ … is improved, but not because of the orthopaedic shoes
- ☐ … has not changed
- ☐ … has deteriorated, but not because of the orthopaedic shoes
- ☐ … has deteriorated, because of the orthopaedic shoes

37. Compared with the period before you received your orthopaedic shoes, your **general health** (not specifically your feet) …

- ☐ … has improved
- ☐ … has not changed
- ☐ … has deteriorated

Current situation

38. Indicate the amount of **pain** you feel in the **skin** of your feet and/or ankles during activities like standing and/or walking.

none ——— very much

39. Indicate the amount of **pain** you feel in the **muscles and joints** of your feet and / or ankles during activities like standing and/or walking.

none ——— very much

40. In the following pictures, indicate the location of your **pain** with a cross.

Right

Left

41. Indicate the amount of trouble you have with **spraining** of your ankles.

none ——— very much

42. Do you have any **wounds/ulcers** on your feet and/or ankles?
- ☐ yes
- ☐ no (if you answer no, continue with question 44)

43. In the following pictures, indicate the location of your **wounds/ulcers** with a cross.

Right

Left

Changes due to your orthopaedic shoes

44. With your orthopaedic shoes, do you have **less or more pain** in the skin of your feet and/or ankles, during activities like standing and/or walking? Indicate the amount of change in pain.

much less ——— much more

- ☐ not applicable

45. With your orthopaedic shoes, do you have **less or more pain** in the **muscles and joints** of your feet and/or ankles, during activities like standing and/or walking? Indicate the amount of change in pain.

much less ——— much more

- ☐ not applicable

46. With your orthopaedic shoes, do you have less or more **trouble with spraining** of your ankles? Indicate the amount of change in trouble with spraining.

much less ——— much more

- ☐ not applicable

47. Have your orthopaedic shoes caused a change to the wounds on your feet and/or ankles? (multiple answers are possible)
- ☐ more wounds
- ☐ bigger wounds
- ☐ no difference
- ☐ less wounds
- ☐ smaller wounds
- ☐ this is for me not applicable

Cosmetic appearance of your orthopaedic shoes

48. Indicate how **ugly or attractive** your orthopaedic shoes are.

very ugly ——— very attractive

49. What do others think of the cosmetic appearance of your orthopaedic shoes?

- ☐ very ugly
- ☐ ugly
- ☐ neutral
- ☐ attractive
- ☐ very attractive
- ☐ I do not know what others think of the cosmetic appearance of my shoes.

Use of your orthopaedic shoes

50. Indicate how poor or how well your shoes **fit.**

very poor ——— very well

51. Indicate if your orthopaedic shoes **fit worse or fit better** than you expected.

much worse ——— much better

52. Indicate how poor or how well you can **walk** in your orthopaedic shoes.

very poor ——— very well

53. Indicate if you can walk **worse or better** than you **expected** in your orthopaedic shoes.

much worse ——— much better

54. Indicate what you think of the **weight** of your orthopaedic shoes.

too light ——— too heavy

55. Indicate if your orthopaedic shoes **lighter or heavier** than you **expected.**

much lighter ——— much heavier

56. Indicate how difficult it is to **put on** and **take off** your orthopaedic shoes.

very difficult ——— very easy

57. With your orthopaedic shoes, do you perform the following activities **less or more** than you **expected?**

- walking inside the house: ☐ less ☐ more ☐ no change
- walking around the garden: ☐ less ☐ more ☐ no change
- housekeeping jobs: ☐ less ☐ more ☐ no change

- shopping for groceries: ☐ less ☐ more ☐ no change
- performing work duties: ☐ less ☐ more ☐ no change
- participating in hobbies: ☐ less ☐ more ☐ no change
- going shopping in town: ☐ less ☐ more ☐ no change
- going for a walk: ☐ less ☐ more ☐ no change
- participating in sport: ☐ less ☐ more ☐ no change

58. How often do you use your orthopaedic shoes?
- ☐ 6–7 days per week
- ☐ 4–5 days per week
- ☐ 2–3 days per week
- ☐ 1 day per week
- ☐ never (continue with question 60)

59. If you use your orthopaedic shoes, how many hours a day do you wear them?
- ☐ more than 12 hours
- ☐ 8–12 hours
- ☐ 4–8 hours
- ☐ 1–4 hours
- ☐ less than 1 hour

60. Do you use your orthopaedic shoes as much as you expected?
- ☐ yes
- ☐ no
- ☐ I do not know

61. How satisfied are you with how much and how often you use your orthopaedic shoes?

very unsatisfied ├──────────────────────────────┤ very satisfied

Review of your orthopaedic shoes

62. Indicate how well the doctor listened to you when your orthopaedic shoes were reviewed.

very bad ├──────────────────────────────┤ very well

63. Indicate how well the **shoe technician/orthotist** listened to you when your orthopaedic shoes were delivered and reviewed?

very bad ——— very well

Further questions

64. Indicate what you think is more important: that your orthopaedic shoes look good or that your orthopaedic shoes solve your foot problems.

Look good ——— solve problems

more important ← equally → more important

65. What are the **advantages** of your orthopaedic shoes?

.....

66. What are the **disadvantages** of your orthopaedic shoes?

.....

67. Indicate whether the **advantages outweigh** the **disadvantages**.

definetely not ——— certainly yes

68. Have your orthopaedic shoes met your **goals**?

- ☐ yes (if yes, continue with question 70)
- ☐ no (if no, continue with question 69)
- ☐ I do not know (if you do not know, continue with question 70)

69. What is the reason that your goals have not been met?

.....

70. Can you describe what you think of the usability of your orthopaedic shoes?

.....

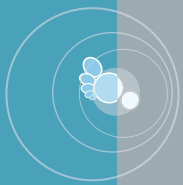
71. Are there any other features/functions that have not been described which affect the usability of your orthopaedic shoes? Please describe.

.....

72. Do you have any final remarks?
How long did it take you to complete this questionnaire?.....minutes

.....

END **Thank you for completing this questionnaire**



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